Vol. VI. NOVEMBER, 1889. No. 7.

AMERICAN METEOROLOGICAL JOURNAL.

A Monthly Review of Meteorology and Medical Climatology.

TABLE OF CONTENTS.

ORIGINAL ARTICLES: PAGE

Theory of Storms, Based on Redfield's Laws. H. FAYE, Membre de l' Institut, etc..... 289

Meteorology at the Paris Exposition. A. LAWRENCE ROTCH..... 292

Distribution of Average Wind Velocities in the United States. (Continued.) DR. FRANK WALDO..... 300

State Tornado Charts. LIEUT. J. P. FINLEY.

Arkansas..... 318

North Carolina..... 322

Dakota..... 326

CORRESPONDENCE:

A Device for Facilitating the Reading of Electrical Anemograph Records. H. HELM CLAYTON..... 330

CURRENT NOTES:

On Certain Theories of Atmospheric Electricity..... 331

Proposed Weather Service in Honduras..... 331

On the Theory of Hail..... 331

Notes..... 332

The St. Thomas-Hatteras Hurricane of September 3-12, 1889..... 333

ANN ARBOR, MICH., U. S. A.:

METEOROLOGICAL JOURNAL COMPANY.

19, 21 and 23 Huron Street.

Single Copies, 25 cents. Per Annum, $2.00. In European Countries, $2.25.

Entered at the Ann Arbor Postoffice as Second Class Matter.

The following Important Book is now Ready.

SEAS AND SKIES IN MANY LATITUDES

OR

WANDERINGS IN SEARCH OF WEATHER.

By the Hon. RALPH ABERCROMBY, F. R. Met. Soc.,
Author of "Principles of Forecasting," "Weather," in the International Scientific Series, Etc.

Demy 8vo, cloth extra, with 3 Maps, 9 Photographs, and 33 Woodcuts by Pritchett, Whymper, Cooper, Etc. *Price*, $4.50.

In this book the author describes his travels in Egypt, Australia, Fiji, India, Borneo, Japan, the United States and the White Sea, Etc., with special reference to the aspect of the sky and the weather from day to day.

Beaten tracks are only noticed sufficiently to bind the narrative together; but less known places, such as the cannibal Islands of Fiji, the edible birds' nest caves of Borneo, and the rich Russian monastery of Solivetzki in the White Sea are fully described and illustrated.

The author in the first chapter gives his impressions of the climate of Canada; and his observations on the influence of battles on weather, made during the war, in front of Petersburg, Virginia.

The last two chapters are devoted to an account of the mountain observatory on Pike's Peak, and to a popular account of the forecasting work, as carried on in the U. S. Signal office three years ago.

London: EDWARD STANFORD, 26 and 27 Cockspur Street, Charing Cross, S. W.

MAILED FREE ON RECEIPT OF POST ORDER FOR $4.50.

By the same Author and from the same Publisher.

INSTRUCTIONS FOR OBSERVING CLOUDS ON LAND AND SEA.

Twenty-two pages. Photo-plate of ten typical cloud forms, and six woodcuts. Mailed free on receipt of 40 cents.

This little book gives clear instructions for naming the leading varieties of clouds; and for determining both the direction of their motion and the direction in which the linear forms of cirrus trend.

The illustrations are taken from all parts of the world, and the instructions are available for any country.

"The instructions for observing clouds which he (Mr. Abercromby) now issues, are undoubtedly an advance over those at present in use.—American Meteorological Journal.

THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. VI. ANN ARBOR, NOVEMBER, 1889. No. 7.

ORIGINAL ARTICLES.

THEORY OF STORMS, BASED ON REDFIELD'S LAWS.

BY H. FAYE,* MEMBRE DE L'INSTITUT, ETC.

Meteorologists have constructed a theory of storms before having studied them, in taking as a basis a single fact which had been long known, *to-wit*, that all storms which burst over a region cause lowering of the barometer at that place.

They begin to see that one fact, badly interpreted, is not enough to base a theory upon. Theirs was annihilated fifty years ago by Redfield's unexpected discoveries. With talent and persistence worthy of a better cause, they have fought against the truth until now, without succeeding in accounting for the most simple and characteristic features of cyclones in a manner at all plausible, that is to say, their gyrations and grandiose progressive motion. Starting with the preconceived idea of a local rarefaction of the air, of an ascending column exercising an aspiration below, a thing is invariably arrived at which neither turns nor progresses. It is easy to confound without knowing it the ordinary theory of depression purely statical, due to slow local variations of temperature, with that of these formidable storms which cross continents and seas in such a path that it can be telegraphed from one shore of the Atlan-

*Translated from M. Faye's manuscript by Mrs. M. W. Harrington.

tic to the other, and can soon be telegraphed from Manilla to China or from China to Japan.

This proves once more that the laws of nature cannot be divined. The only way of arriving at a knowledge of these laws is to study facts in themselves without seeking to bend them to a preconceived idea.

This has been Redfield's method, and that of his successors, Reid and Piddington. In a series of works worthy of all admiration, the laws which he discovered in following the true scientific method are, for meteorology, the equivalent of the laws which Kepler discovered for astronomy in following the same path. I have taken them for the point of departure of my theory.

1.—*Interpretation of the Laws of Storms.*

After the discovery of Kepler's laws there remained to be deduced from them the central force of the sun, and the mechanical constitution of the planetary system. After the discovery of Redfield's laws there was also something to do; it was to deduce from them the mechanics of the immense vortices traveling with an almost geometric regularity from the equator to the poles.

If the first question was taken up and fully solved by mathematical analysis, it was because the branch of rational mechanics, which had to be applied, existed already, thanks to the labors of Galileo, of Huyghens and, above all, of Newton. By analysis there was deduced from these laws all that they contained in embryo; and even all that was incomplete in the first announcement was corrected.

It is not thus in the gyratory movements of liquids or gases. The known equations in hydrodynamics founded upon the continuity of a fluid in movement, and upon the equal transmission of pressure in all directions, which would apply very well in an ordinary case where winds originate in a simple difference of pressure between adjacent isobars, would not apply at all in a case where it is a question of fluids of which the layers or threads traverse each other mutually either in ascending or descending, and where the equal transmission of pressures is

notably altered under the furious gyrations which are superposed and which succeed each other in the atmosphere. What can be done in such a case? Is not the surest way to seek out in nature other gyratory movements, quite as characteristic as the storms, but nearer, more familiar, more accessible, in order to examine their mechanism? The first difficulty with cyclones is that only the lower part can be observed; the vast mouth can not be seen; nothing tells us how the gyrations behave themselves above the thick layer of clouds which conceal them from our sight.

The same difficulty occurs in small cyclones, *trombes* or tornadoes, of which one can take in at a glance the lower part, of which the form is clearly defined by a cylindro-conic surface of revolution, but of which the mouth is lost in the clouds.

As to the gyrations, which are produced artificially, by the aid of a sort of ventilator in a vase full of water or even in the air, the analogy does not go far. In the first place we cannot imagine anything in the atmosphere resembling in any degree a rotary apparatus; besides the gyrations thus produced, whirl very well but do not travel. Now as all atmospheric whirls without exception, travel as they turn, it may well be believed that these two movements are intimately connected, and that one is as necessary as the other. There remain the whirls of our rivers and streams, which turn as they travel like cyclones, following a trajectory determined by the course of the water. Their beginnings and their ends may be observed. I have consulted engineers upon this subject, who are especially occupied with the subject of running waters,—Venturi in the past, Pouclet, Belgrand, St. Venant and Gen. Morin of our time. That which I learned from them has encouraged me to persist in this path. All these whirls have vertical axes. Some are constantly produced against certain obstacles, around axes diversely inclined to the horizon; but *these* cannot last; they are soon reduced to tumultuous movements like the turbulence of the waves of the sea. It is not necessary to suppose that there are opposing currents; these whirls arise naturally from the simple inequality of velocity which often exists between

parallel threads. Their form, which can sometimes be made visible by projecting light dust into the current, is limited by a cylindro-conic surface of revolution. Their mouths, perfectly visible, are funnel shaped. Everything that floats is drawn into them—ice, swimmers, even boats are swallowed up. The energy of their gyration, narrowed more and more toward the bottom, accumulates at the lower end. There, they work like a cyclone or a tornado. They travel horizontally, leveling obstacles, and scouring the bed of streams or rivers. Engineers, who have observed the course of the Mississippi, must have had frequent occasion to observe these phenomena. Finally they are formed of all dimensions from a few inches to scores of feet, just as atmospheric whirls are seen of all sizes, from the small whirl of dust, which moves along our streets or public squares in stormy weather, to the immense cyclone which covers an entire country. Have these not characteristics similar to cyclones or to their varieties *trombes* and tornadoes? If there are in the atmosphere currents similar to those of the ocean, but much more rapid, you may affirm positively, said M. Belgrand, that whirls form there. Undoubtedly the identity cannot be complete between the phenomena of an incompressible liquid like water and those of an elastic fluid like the air, charged with condensable vapors. We will first discuss the pure mechanism of whirls, and follow with the conditions which are more particularly physical.

[TO BE CONTINUED.]

METEOROLOGY AT THE PARIS EXPOSITION.

By A. Lawrence Rotch.

I.—THE FRENCH SECTION.

The exhibition of meteorological instruments is disappointing, since neither England nor Germany contribute to it. The only governments represented are France and the United States.

The French Central Meteorological office shows the instruments used at its secondary stations, and the Redier barograph and anemograph, besides charts and other publications. The

municipal observatory of the city of Paris in the park of Montsouris displays a number of instruments presenting little novelty. Much attention has been given at Montsouris to the study of actinometry (see this JOURNAL, March, 1889), and this is illustrated by various actinometers. There is the Herschel-Arago actinometer, the vaporization radiometer of Bellani, and Crooke's radiometer with reduced velocity and a counter of revolutions. The Richard registering actinometer has bright and black bulbs in vacuo which, being connected with two thermometers, trace curves, the difference of whose ordinates at night as well as in the day-time give at each instant a measure of the radiation from the sky. In the modified actinometer and pyrheliometer of P. Desains, which serves to measure the variation of the quantity of vapor contained in the whole atmosphere, the intensity of the solar rays can be reduced in a constant proportion by interposing different thicknesses of water before the pile which is connected with a galvanometer. The Arago photometer has a telescope equatorially mounted, with a Foucault and a bi-refracting prism giving two images of the object, which is moveable around a graduated circle. It serves to measure the relative brilliancy of the sun and the transparence of the air during the night. The thermographs, hygrographs, pluviographs and anemographs have no new features, except in the latter it is noted that the speed of rotation of the cylinder on which the velocity is recorded can be increased in order to study squalls. There are various appliances for the collection and analysis of air and meteoric waters, which form a special service at the Montsouris observatory.

The exhibit of Richard brothers of Paris is most interesting. The Richard thermographs, barographs, etc., are well known, but the anemometers merit notice, as embodying new principles. In the first place, these constructors have discarded as a motor the Robinson cups, which possess too much inertia and an uncertain velocity of rotation as compared with the velocity of the wind, and have replaced them by a fan wheel formed of six blades of aluminum inclined at 45° and fastened to a very light axis. The diameter of the wheel is calculated so that one

revolution corresponds to a meter of wind, and this relation is verified by experiment on a whirling arm and a table of correctness furnished, if necessary. The wheel is kept facing the wind by a vane with a divergent tail. Placed in the wind this fan-wheel, weighing only 150 grammes, may be compared to a feather carried by the lightest currents. The new registers of wind velocity, called *cinemographs*, are based on the division of the space traversed by the time occupied, which is done mechanically as follows: An endless screw working in a wheel turned by the wind carries a roller which rests on a disk. The wind's motion tends to move the roller away from the center of the disk which, being turned at a uniform rate, tends to bring the roller to its center, and its position on the disk will correspond to the relation of the two factors, time and space moved over by the wind. The idea of employing a roller and disk in an integraph is not new, but the novelty consists in preventing slipping by two disks turning in opposite directions, which compress the roller by a spring. Practically the anemo-cinemograph has two clock work movements, one turning the two disks by the intervention of a Foucault or a conical pendulum regulator, the other turning freely, unless stopped by an electro-magnet, connected with the anemometer which establishes the electric contacts. This movement carries the tangential wheel which drives the screw carrying the roller. The operation is thus effected: The disks turning in function of the time bring constantly the roller towards their axis, but the wind, allowing the other movement to run faster or slower, by means of the endless screw, causes the roller to recede from the axis. When there is equilibrium between the two movements the position of the roller is momentarily fixed, and a lever attached to the screw traces by a pen the wind's velocity on a revolving cylinder. The apparatus is adapted to give the direct velocity per second, or to give the mean velocity per second, by giving the disks different speeds of rotation, and by changing the number of contacts. In the first case a contact is made for each 50 cm. of wind, and to register it the speed of the paper should be at least 3 mm. per minute, or 4 m. per day. In the second case, a con-

tact is made for each 50 m. of wind only, and the registering paper is contained on a cylinder turning once a day. To regulate the cinemographs a chronograph with a toothed cam breaks and makes an electric circuit just as the anemometer would do. The number of teeth on the cam can be altered so that it can be seen if the heights of the inscribed ordinates are proportional.

The anemometer of Parrigou-Lagrange, giving a diagram of the vertical component of the wind, has been perfected by the Richard brothers. Its motor is a wheel with inclined vanes placed horizontally, which at each revolution establishes three contacts, each being connected by a wire with the register. This is an electric motor with three electro-magnets symmetrically arranged around a cross with four arms. Each magnet being connected with one of the above contacts and a pile with a continuous current being in the circuit, when the wind-wheel turns in the direction caused by ascending currents of air, the iron cross piece turns in one direction; when the wheel turns in the direction which descending currents give it, the cross turns in the opposite direction. These revolutions are transmitted to a vertical cylinder which is thus displaced proportionally to the space passed over by the wind. As a pen descends the cylinder diagrams are obtained in which the abscissæ give the turns, the ordinates the space traversed, and the curve indicates the upward or downward movement, whose velocity is shown by the tangent of the angle which the curve makes with the horizontal.

Various other interesting instruments are exhibited by this firm, but only one other will be mentioned. In the new hygrograph, a bundle of hairs, on Klinkerfuess' system, has been substituted for the slice of horn, formerly employed. The hairs act at an obtuse angle upon a bell-crank lever, and by means of two cams rolling on each other their elongation or contraction are registered on the cylinder. The hairs give much greater sensitiveness than the horn and by the new mode of transmission equal degrees of humidity are represented by nearly equal divisions on the register sheet, which was not the case before. An interesting application of the Richard instruments has been made by transmitting the indications of some of them—notably

the thermometer, the wind direction and horizontal and vertical velocities,—from the top of the Eiffel Tower, 300 m. above the Champs de Mars, to the registers in the Palace of Liberal Arts. Similar instruments are in use at the Central Meteorological Office, not far distant, and the two sets of observations are now being reduced by M. Angot. Later it is proposed to place thermographs directly at the foot of the tower and at heights intermediate between the base and summit in order to study the vertical distribution of temperature.

L. C. Baudin, of Paris, shows some very fine standard thermometers. The progress which he has made in this work since 1878 is as follows: June, 1883, invention of the mercurial thermometer reading to 460° C. 1885, construction of the alcohol thermometer, giving indications comparable to the air thermometer between 0° and — 100° C. It was through Mr. A. C. White, of the Massachusetts Institute of Technology, that this thermometer was constructed. December, 1887, construction of annealed thermometers by the method of Crafts and Friedel. Baudin, who claims to have been the first maker to adopt this method of obtaining an invariable zero, has since modified the method and is prepared to furnish thermometers which will always return to the same zero within a thousandth of a degree, whatever may be the number or length of the boilings. Under these conditions the hypsometric thermometer is preferable to the mercurial barometer for the measurement of heights, and permits of a closer approximation. Thus the hypsometer shown, which measures only 500 m., permits differences of level of 0.50 m. to be read. The price of a standard thermometer, divided in 0.1° C. from — 1° to + 101°, and guaranteed exact to within 0.08° C. for the whole scale, is only 55 francs ($11). The annealing process has also been applied to maximum and minimum and other thermometers for meteorological use. J. Tonnelot, of Paris, shows the standard thermometer of green glass, divided to 0.1° C., constructed for the International Bureau of Weights and Measures, as well as some finely finished Fortin and Renou barometers. In the latter form the cistern is large and but one adjustment is necessary in reading. The thermom-

eter of M. Janssen for ascertaining the temperature of springs, etc., has the bulb surrounded by loose strings which retain the water when the thermometer is drawn out.

Golaz and Son show several forms of dew-point apparatus. That of Regnault is well known to physicists, but is little employed in meteorological observations. The Alluard condensation hygrometer is a modification of it, and consists of a hollow square prism of polished brass, having one of its faces surrounded by a polished brass frame which, however, does not touch the prism. Since this frame is never cooled below the air temperature it remains bright and the deposition of dew is easily observed by the contrast of the face of the prism, cooled by the evaporation of ether within, and the surrounding frame which retains its polish. A thermometer dips into the ether contained in the prism which is agitated either by blowing or aspirating air through it. The temperature of the adjacent air is determined by means of a sling thermometer. The apparatus packs compactly in a box for transportation, and its price is 120 francs ($24). The hygrometer with internal condensation of M. Crova was designed to meet the case when the air being in motion and the dew-point much below the air temperature, the air moves over the surface of the metal without completely establishing equilibrium of temperature so that the humidities obtained are too low. The apparatus consists of a thin brass tube, nickeled and polished inside. One end is closed by ground glass, and at the other is a lens permitting the interior of the tube to be seen while a black screen eliminates the effect of the exterior light. The tube is fixed in the axis of a prismatic brass box filled with sulphuret of carbon and furnished with two stop-cocks, by one of which a current of air is blown in by the mouth, cooling the solution and tube by evaporation, while from the other the air charged with vapor is discharged. A thermometer passes through the box and is in contact with the tube. The external air is drawn by the action of a rubber bulb through the tube which is cooled as before described until its brilliant interior is seen to become spotted with moisture. These spots are allowed to disappear, and at that instant the

temperature of the dew-point is read from the thermometer to within 0.1° C. The dew-points thus obtained are always higher than those given by hygrometers with external condensation. In calm, warm and damp weather, the differences are small, but they increase with the motion and dryness of the air. The Crova apparatus complete costs 130 francs ($26).

The barograph of G. Raymond is sensitive to small changes of pressure, and is constructed as follows: A float in the short leg of a siphon tube acts by a cord upon an arc fixed on the shorter arm of a lever. The other end of the lever traces its motion by a fine needle upon a vertical drum covered with lamp-blacked paper. The drum is turned on its axis by clock work and the trace is fixed permanently on the paper by covering it with gum solution. As the column of mercury which carries the float is short, the small temperature correction appears to be neglected. This instrument, which costs 280 francs ($56), is in practical use at the Park of St. Maur observatory.

Naudet & Co., Paris, have a fine exhibit of aneroid barometers for whose manufacture they are noted. It was this firm which in 1860 perfected the holosteric barometer invented by Vidi by substituting for the spiral spring employed by him to resist the atmospheric pressure, an arched steel spring, and also compensating the effect of temperature by making of two metals the lever which transmits the movement of the counter-spring to the dial needle. No radical improvements have since been made in the construction of aneroid barometers, but their price and size have been much reduced. Thus, Renaut of Paris sells an aneroid with a copper case and a card dial for the wonderfully low price of 3 francs 50 centimes (*70 cents*), and has pocket instruments for mountain use at 12 francs ($2.50).

A model of the anemograph invented by E. Bourdan, in 1882, and perfected by his sons, is exhibited. This apparatus, which is little known to meteorologists at large, depends on the effect which the convergent-divergent tubes of Venturi have of producing at the point of reunion of the truncated cones, a vacuum which is greater than that produced by the entering current of

air. M. Bourdan placed, one behind the other, several concentric tubes of this form, but of decreasing diameters and small enough to occupy only the central part of the contracted section of the outer tube. Ordinarily, the anemometer has two tubes, but if the instrument is designed to measure small velocities a third tube may become necessary. The action is as follows: When there is a single tube there is produced at the point of intersection of the two cones a suction caused by the contraction of the fluid vein at this place. If a second tube be fixed so that its divergent extremity is exactly at the point of intersection where the fluid vein attains its maximum contraction, the air will flow into this tube, not only by virtue of the propulsion which the current has as a whole, but still more by the influence of the atmosphere which exerts all its weight on the entering orifice whilst the exit is immersed in a medium where the air is considerably rarefied. The relations of the vacua at the entering orifice of the bi-conical tube and at the point of intersection, as determined by a manometer, are as 1 to 6. If a second and third tube of the same shape, but decreasing dimensions, be placed one behind the other the effect will be to increase the vacuum and, consequently, the velocity of flow of air produced in the last tube, the increase being 1 to 20 with two tubes and 1 to 80 with three. In the anemometer as constructed the Venturi tube is connected by a pipe with a hermetically closed box having a flexible diaphragm by which the variations of pressure are continually traced upon a horizontal cylinder turned on its axis by clockwork. By the movement of the Venturi tube, which is pivoted so as to face the wind, the direction is registered upon another portion of the cylinder by means of pens actuated by cams. This apparatus has the advantage of simplicity and by magnifying considerably the scale of velocities accurate results may be obtained. Since there is only the friction of the air upon the sides of the tube the transmission of the movement is not sensibly diminished, and each gust of wind is instantaneously registered just as it occurs. The resistances and friction remain nearly constant and the conical form of the tube counteracts small inclinations in the wind's axis, though

the tube does not easily put itself in the direction of the wind when its velocity is small. There is, however, a considerable difficulty in determining experimentally the velocity of the air entering the tube in order to form the scale of the register. Such anemographs are in use at the observatories of Paris and Perpignan and at several foreign observatories.

(TO BE CONTINUED).

DISTRIBUTION OF AVERAGE WIND VELOCITIES IN THE UNITED STATES.

INVESTIGATED BY DR. FRANK WALDO.

(CONTINUED FROM OCTOBER NUMBER.)

SECTION IV. COMPARISON OF AVERAGE WIND VELOCITIES WITH OTHER ELEMENTS.

One naturally turns first to the Barometric Minima or "Lows" in order to note the relationship between these and the mean wind velocities. This is done for both the average number of Minima and for their average velocity.

In the Signal Service Summary and Review for International Meteorology for 1886, I find the following values given for the number of lows:

Month.	Average number of Lows.	Number of years used.
January	13.2	12
February	11.8	12
March	12	12
April	10.6	13
May	8.4	12
June	9	12 (?)
July	9	13
August	9.5	13
September	9.2	14
October	10.5	13
November	11.7	—
December	12.4	—

Also in the Monthly Weather Reviews in the Chief Signal Office Annual Report for 1883, are the following tables; giving the number of "Lows" traced during each month:

TABLE IV.—*Number of "Lows" observed in U. S. for each Month.*

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Y.
1873	—	—	—	8	10	10	13	12	11	13	12	12	—
1874	8	12	12	13	8	9	11	11	13	9	10	12	128
1875	12	14	11	10	11	7	8	7	8	10	14	9	121
1876	12	10	8	13	11	6	8	8	10	9	15	15	125
1877	14	12	12	9	5	11	8	10	8	11	12	15	127
1878	12	12	17	9	13	10	11	14	12	13	14	8	145
1879	15	9	18	18	14	9	9	11	7	9	18	21	148
1880	18	15	16	14	10	13	12	16	13	12	16	15	170
1881	9	10	10	7	5	6	5	6	7	6	16	10	97
1882	14	11	10	11	4	9	6	10	4	13	5	10	107
1883	16	10	11	9	9	8	—	—	—	—	—	—	—
Mean..	13.0	11.5	12.5	12.0	9.1	8.9	9.1	10.5	9.1	10.5	13.2	12.7	

The maximum and minimum of these annual sums in column Y agree fairly well with the dates of maximum and minimum winds as found in the preceding section for most of the stations. The velocities of the Lows in the United States for the years 1872–1884, is given by Loomis* in his 21st Article in the American Journal of Science, but is here reproduced (reduced to miles per hour) from the *Meteorologische Zeitschrift*, December, 1886, page 466.

Month.	Average velocity miles per hour.
January	33.8
February	34.4
March	31.5
April	27.6
May	25.5
June	24.4
July	24.6
August	22.6
September	24.6
October	27.6
November	30.0
December	33.4
Year.	Mean 28.4

It is seen that in neither the average number of Lows nor in the average velocity does the maximum occur in March or April

*During the preparation of this paper I have not had access to Loomis' papers (except some reviews of them,) and so have been unable to see and utilize what he has done on the subject treated in this section.

as is found for wind velocities, but they both agree more nearly with the minimum of temperature, as they occur in January and February respectively. The minimum velocity of "Lows" occurs in August, however, and thus is coincident with the minimum of wind velocities. The minimum of frequency of "Lows" appears to occur a little earlier in the summer, but the difference for the summer months is very slight. I had expected to find a better agreement than this between the annual march of "Lows" and wind velocities, because modern meteorology teaches us that the distribution and changes of atmospheric pressure are the ruling causes in forming the laws of distribution of many of the other elements. On looking around for soms explanation of this unexpected difference found for the Winter Maxima, I found that, at any rate, a partial explanation was to be found in the data given in Finley's paper on "Relative Storm Frequency, etc.," forming Signal Service Professional Paper No. XIV.

Finley has given the number of "Lows" for various regions and I have combined his separately given data, thus: "Storms beginning and ending in North America" + "Storms beginning in North America and ending in the North Atlantic Ocean" + "Storms beginning in North America and crossing the North Atlantic" + "Storms beginning in North America and crossing the North Atlantic and Europe." It seems as though these sums should represent the total number of North American storms, and they are given in the following table:

TABLE V.—*Number of "Lows" observed in North America.*

Year.	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Y.
1873	**12**	**10**	**11**	**7**	**10**	**10**	**13**	11	16	19	18	11	(148)
1874	8	12	14	19	11	14	15	21	15	18	15	22	184
1875	15	21	16	12	15	18	12	9	15	14	17	10	174
1876	16	15	17	19	18	8	11	13	12	13	17	**15**	(174)
1877	16	13	15	13	8	13	11	11	19	13	13	9	154
1878	16	13	22	(13)	10	9	10	13	8	11	12	9	(146)
1879	13	13	14	15	16	10	12	9	8	10	15	22	157
1880	14	16	16	15	9	9	7	10	14	11	10	15	146
1881	11	9	10	11	6	7	9	10	7	6	16	10	(112)
1882	14	11	10	11	4	9	6	10	4	13	6	11	(109)
1883	15	10	11	9	9	8	9	8	9	9	—	—	
Mean.	13.6	13.0	14.2	13.1	10.5	10.5	10.5	11.4	11.5	12.5	13.9	13.4	

The storms just off the eastern coasts are evidently not included here, and their effects are of course felt at the land stations.

While there is apparently a *minimum* just before the year 1873 and again about 1882, yet the intervening *maximum* occurs before that found by the officially published Signal Service tables.

In this table the numbers in heavy type are copied *directly* from the list given by Finley as not used in his classified tables. This table shows a maximum frequency in March and a minimum in July, which more nearly accords with the phases of the wind velocities. And here too we find the secondary fall maximum occurring in November just as for the wind velocities. Here, then, we have a concurrence of phases in the curves showing the annual march of surface wind velocities and the number of "Lows" in *America:* and it is necessary to take into account the "Lows" passing over British America in any such comparisons, for the influence of these lows is felt on the wind circulation far within the United States. These results would seem to indicate that, for the colder months at least, the effects of the "Lows" on the wind velocities are felt over a wider path near the surface of the earth, than at an elevation of 6,000 feet above the sea-level.

It will be a little more exact to give these average results for each month divided by the number of days in the month, as these ratios will then be for equal lengths of time. We get then

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Sig. Ser. Table.	.43	.42	.39	.35	.27	.30	.29	.31	.31	.34	.39	.40
Finley's Data.	.44	.46	.46	.40	.34	.35	.34	.37	.38	.40	.46	.43

Note.—The relation of maximum to minimum of number of lows, for the months of the year, and the maximum to minimum of wind velocities, seems to be about the same, *i. e.*, 1.5; but the subject has not been studied in detail.

Perhaps the same may be the case for the average monthly velocities of "Lows"; but I have not available the average velocities of all of those "Lows" included in Finley's tables, and so the comparison cannot be made.

The depth of the "Lows" has, however, the greatest effect on the wind velocities. It is not necessary to quote here any of the

results obtained by those workers in Dynamical Meteorology who have investigated both theoretically and by means of observations the relation of atmospheric pressure gradients to wind velocities, but we wish to compare the depth of the Lows with the average wind velocities. Unfortunately there is not at hand any table of the average depths of all the "Lows" in each month,* so that a somewhat different comparison has been made from what would have been the most desirable. From the Chief Signal Officer's Report, 1885, there has been taken from the table, the average of the lowest and highest barometer reading occurring at the following places: Boston, Augusta, Key West, Grand Haven, Cairo, Dodge City, Salt Lake City, San Francisco, Pike's Peak, and Mt. Washington. These averages are made up of from 10 to 14 years observations.

(Dr. J. van Bebber, in treating the subject of European Barometric Minima in the Oster. Zeitschrift für Meteorologie, Band XVII (1882), p. 305, says: "Es ist jedenfalls von Bedeutung dass sich diese extreme durch nicht complicirte curben übersichtlich darstellen lassen und man auf diese Weise im Grossen und Ganzen fast dasselbe Beld erhält, wie bei Darstellung der Mittleren Tiefen." It was this remark which suggested to me to use the mean of the lowest observed barometric pressures at the different stations, in place of the average of the pressure in the Lows).

The following table contains these data. Under each of the stations, Column 1 contains the mean of the *highest* barometer readings *reduced to sea-level;* Column 2 contains the mean of the *lowest* barometer readings *reduced to sea-level;* Column 3, the difference of Column 1 and Column 2, or the mean range; and for Dodge City, Salt Lake City, San Francisco, Pike's Peak, and Mt. Washington, Column 4 is the *actual reading* corresponding to Column 1, and Column 5 is the *actual* reading corresponding to Column 2.

* Loomis probably gives this, but his works cannot be conveniently consulted.

TABLE VI.—*Comparison of Extremes of Atmospheric Pressure and Average Wind Velocities.*

	Boston.				Augusta.				Key West.				Grand Haven.				Cairo.				
	R. H.	R. L.	Dif.	Wind	R. H.	R. L.	Dif.	Wind	R. H.	R. L.	Dif.	Wind	R. H.	R. L.	Dif	Wind	R. H.	R. L.	Dif.	Wind	
J	30.67	29.31	1.36	9.9	30.62	29.65	.97	3.5	30.35	29.90	.45	10.9	30.59	29.45	1.14	11.7	30.76	29.65	1.11	7.8	J
F	.68	.24	1.44	10.6	.57	.66	.91	4.3	.30	.91	.39	10.3	.62	.38	1.24	12.2	.64	.51	1.13	8.6	F
M	.55	.17	1.38	11.3	.52	.60	.92	4.9	.31	.88	.43	11.2	.51	.25	1.26	12.0	.53	.49	1.04	10.0	M
A	.40	.29	1.11	10.1	.37	.60	.77	4.4	.22	.81	.41	10.5	.37	.31	1.06	11.7	.33	.48	.85	9.0	A
M	.42	.51	.91	8 8	.31	.71	.60	4.0	.14	.83	.31	9.4	.37	.50	.87	10.6	.29	.65	.64	7.5	M
J	.33	.52	.81	7.8	.27	.75	.52	3.9	.16	.91	.25	7.7	.25	.49	.76	9.0	.22	.67	.55	6.5	J
J	.24	.62	.62	7.4	.26	.79	.47	3.3	.17	.93	.24	7.5	.21	.62	.59	8 4	.22	.78	.44	5.3	J
A	.32	.63	.69	7.1	.26	.80	.46	3.1	.13	.86	.27	7.3	.25	.66	.59	8.2	.23	.78	.45	4.9	A
S	.43	.57	.86	8.2	.31	.71	.60	3.4	.12	.77	.35	8.2	.37	.59	.78	10.0	.31	.77	.54	5.8	S
O	.53	.43	1.16	9.0	.46	.72	.74	3.6	.17	.65	.52	11.8	.46	.46	1.00	11.8	.47	.71	.76	6.6	O
N	.60	.26	1.34	10.3	.54	.72	.82	3.6	.23	.82	.41	11.2	.54	.38	1.16	12.3	.60	.66	.94	7.8	N
D	30.65	29 29	1.36	10.0	.58	29.67	.91	3.3	.30	29.86	.44	11.1	30.57	29.40	1.17	12.1	30.65	29.61	1.04	7.8	D
Max.	n	y	n nearly		n	y	n		n	y	y		y	y	y		n	y	n		
Min	n	y	y nearly		y	y	y		n	y nearly	y nearly		y nearly	y	y		y	y	y		

	Dodge City.						Salt Lake City.						San Francisco.				Pike's Peak.						Mt. Washington.						
	R.H	R. L.	Dif.	O.H.	O. L.	Wind	R.H	R. L.	Dif.	O H.	O. L.	Wind	R.H.	R. L.	Dif.	Wind	R.H.	R. L.	Dif	O.H.	O. L.	Wind	R.H.	R. L.	Dif.	O H	O. L.	Wind	
J	30.55	29.32	1.23	27.80	26.57	10.9	30.49	29.60	.89	25.92	25.03	4.0	30.44	29.65	.79	7.1	30.17	29.48	.69	17.47	16.78	25.0	30.40	29.17	1.23	23.77	22.54	43.6	J
F	.40	.22	1.18	27.66	.48	11.5	.47	.59	.88	.91	.03	4.4	.44	.68	.76	7.3	.19	.49	.60	.47	16.77	25.3	.36	.14	1.22	.74	.52	42.8	F
M	.36	.10	1.26	.63	.37	14.0	.37	.54	.83	.85	.02	5.9	.34	.73	.61	8.9	.22	.46	.76	.63	16.87	25 3	.32	.13	1 19	.80	.61	38.7	M
A	.22	.06	1.16	.58	.42	14.9	.24	.50	.74	.87	.13	6.4	.32	.71	.61	10.0	.14	.43	.71	.86	17.15	21.3	.32	.24	1.08	.91	.83	31.6	A
M	.04	.04	1.00	.49	.49	14.5	.19	.58	.61	.87	.26	6 5	.20	.81	.39	11.2	.15	.55	.60	18.09	17.49	21.5	.41	.49	.92	24.25	23.31	29.7	M
J	30.02	.28	.74	.41	.77	13.3	.13	.59	.54	.91	.37	6.2	.17	.78	.39	12.5	.25	.76	.49	18.43	17.94	19.0	.43	.67	.76	.31	.55	30.2	J
J	29.98	.38	.60	.48	.88	12.6	.09	.65	.44	.91	25.47	5.7	.11	.78	.33	12.8	.31	30.00	.31	.53	18.22	12 7	.38	.75	.63	.31	.63	28.7	J
A	30.03	.40	.63	.55	.92	11.1	.11	.68	.43	.92	.49	5.7	.13	.78	.35	12.0	.30	29.95	.35	.51	18.16	12.0	.44	.82	.62	.36	.74	28.5	A
S	.16	.34	.82	.61	.79	12 4	.22	.64	.58	.97	.39	5.5	.13	.76	.37	9.9	.29	.82	.47	.31	17.84	16.1	.47	.65	.82	.32	.50	31.8	S
O	.33	.29	1.04	.70	.66	12.0	.33	.61	.72	.93	.21	4.9	.25	.77	.48	7.7	.31	.63	.68	18.03	17.35	21.1	.45	.46	.99	24.15	23.31	32.1	O
N	.51	.33	1.18	.77	.59	10.4	.53	.69	.84	.96	.12	3.9	.37	.79	.58	6.1	.35	.61	.74	17.69	16.95	19 7	.44	.24	1.20	23.88	22.68	35.6	N
D	30.52	.30	1.22	27.72	26.50	10.3	30.53	29.64	.89	25.99	25.10	3.9	30.39	.67	.72	6.6	30.27	29.49	.78	17.61	16.83	22.2	30.41	29.15	1.26	23.78	22.52	39.2	D
Max.	n	y	n	n	y		n	y	n Rev.	n nearly Rev.	n		n	n	n		n	y (?) nearly	y nearly	n Rev.	y		n	n nearly y	n nearly y	Rev.	y		
Min.	n	n (?)	n	n	n (?)		n Rev.	n (?)	n Rev.	n Rev.	n Rev.(?)		n	n	n		n	y	y (? nearly	n Rev.	y		n Rev nearly	y	y	Rev.	y		

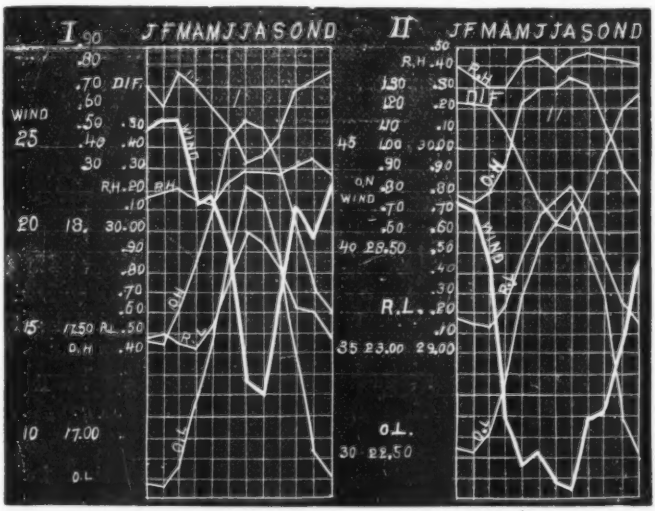
We wish now to find the relation existing between these barometric readings and the mean wind velocities, and in order to show this, there is given at the foot of each column a double row of letters, either the letter *n* or *y* occurring; these letters standing for *no* and *yes* respectively. The *first horizontal row* of letters shows the connection of the *greatest* monthly wind with the *highest*, *lowest* and *greatest range* of barometer reading; that is, the concurrence of the maximum wind with the maximum pressure in Column 1 is indicated by *y*, the non-concurrence by *n*; in Column 2 the concurrence of maximum wind with minimum pressure is indicated by *y*, the non-concurrence by *n*; in Column 3 the concurrence of maximum wind with maximum range of pressure is indicated by *y*, the non-concurrence by *n*.

The *second horizontal row* of letters shows the connection of the least monthly wind with the highest, *lowest* and *range* of the atmospheric pressure. In Column 1, *y* indicates concurrence of minimum wind with the minimum of highest barometric pressure; in Column 2, *y* shows the concurrence of minimum wind with maximum of lowest pressures; and in Column 3, *y* shows the concurrence of minimum wind with minimum range of barometric pressure.

In the cases where it seems a little undecided, a (?) is inserted, and in case the exact opposite is found, the abbreviation *Rev.* (reversed) is used; in some cases the word *nearly* is given to show that the condition is almost fulfilled, and it may be due to some accidental circumstances that it is not quite so.

It will be seen that in nearly all the cases for the stations at low elevations there is a coincidence between the highest winds and the lowest minimum pressure and greatest range; and the least winds and highest minimum and least range. For the highest and lowest maximum pressure, however, these are not always accompanied by the greatest and least winds respectively; the former especially not occurring frequently. For the high lying stations the relations of the winds to the maximum pressure seems to be reversed especially for the actual pressure not reduced to sea level.

The accompanying diagram shows the data for Pike's Peak (I), and Mt. Washington* (II), as given in the previous table. The first vertical column refers to the wind, in which each small division is one mile per hour. The second vertical column refers to the differences of extremes and to "observed highest" and "observed lowest;" one division being 0.10 of an inch. The third vertical column refers to the "reduced highest" and "reduced lowest" and in this case, also, one division is 0.10 of an inch. The average wind movement is given by a



broader line than those referring to the barometric data. Opposite the beginning of each of the curves, as well as on the curves, are found the letters used in the headings of the preceding table.

A point which can only be touched on here and which it would be of interest to investigate fully, is one that has been mentioned quite frequently of late, especially in this country,

*The average winds for Mt. Washington are taken from Greely's paper in this JOURNAL, Vol. V, and I had previously collected all the published monthly winds for Mt. Washington but found them of almost no value, on account of the presence of frost work on the anemometer.

viz., the effect of the wind on barometer readings. If the force of the winds affects the barometer readings for single observations, then this must be noticeable in a more or less slight degree in the average for the wind velocities. This would be particularly noticeable in the case of comparing mountain stations with lower and less exposed stations. In view of the various results obtained by different writers for the annual march of the differences, barometrically determined (by Laplace's formula), in elevation between high and low lying stations, I shall forbear making any strict comparison between these, and the annual march of the wind velocities. However, for Pike's Peak and Dodge City the maximum differences in elevation occur about July or August and the minimum in December or January. In the present paper it is shown that for the winds, Pike's Peak —Dodge City has a minimum in July and a maximum in January; also for Pike's Peak – Dodge City the same is true. This shows that for this case, at least, a maximum of difference of wind is accompanied by a minimum of difference in barometer readings and vice versa.

For Mt. Washington and Portland nearly the reverse of this is true, for the maximum of difference of elevation occurs in the winter or early spring months with the maximum difference in wind velocity; and the two minima occur in mid-summer.

Concerning investigations of the relation of wind velocities to differences of elevation for short periods of observation, I will only refer to the writings of Hazen and Gilbert.

The charts of Mean Barometer Pressure for the year, January and July, published by Prof. Ferrel in the Chief Signal Officer's Annual Report for 1886, do not seem to offer any reason for the corresponding distribution of wind velocities except for one locality, viz., the great plains east of the Rocky Mountains. The pressure distribution for the year shows a slight High on the east and northwest parts of the United States. This, according to the law of circulation of winds, would give a southeast wind on the southern plains and a northeast wind on the northern plains, thus causing the winds to pass along an unprotected slope; and meeting with little resistance they gain in force.

For January, the charts of Prof. Hazen show a High on the plateau near Salt Lake, and this gives rise to the westerly winds shown by him and computed by Lambert's formula. For July, the Low on this plateau causes the southerly and easterly winds which, coming over the prairies, cause the excessive wind velocity at this season.

So far as temperature is concerned, these strong winds blow the cold air east and south in winter and the warm air north in summer, but an examination of the unreduced (to sea level) charts of Greely and the reduced (to sea level) charts of Ferrel rel and Hazen shows very little connection with the wind velocity.

The comparison of the annual march of wind velocities with the annual march of cloudiness for a good many stations failed to show any general connection for all localities. At some stations the curves agreed, and at others the maximum of one occurred at the minimum for the other. In regard to annual amounts, both seem to increase with the nearness to the paths of greatest frequency for "Lows," at least for the eastern part of the United States.

The effect of the wind distribution on evaporation must be very considerable, but it would be very difficult to establish the relation on account of the various elements entering into the question of evaporation. Prof. Russell has given some very interesting results on the increase of evaporation with increased wind velocity, when the evaporimeter remains under otherwise constant surroundings. He finds that a Piche Evaporimeter attached to the free end of a Combe's whirling apparatus (having an arm of 23 feet length) gave the following results:

Velocity, miles per hour*	0	5	10	15	20	25	30
Evaporation (relative)	1.0	2.2	3.8	4.9	5.7	6.1	6.3

The observations were made at Washington on two days in June, 1883, the average temperature being 87° F. and the relative humidity 50 per cent. This shows that up to about 20 miles per hour the increase is very rapid, but after that the increase

*Actual distance passed over, and not anemometer miles.

of wind made little difference, but this last may be in some measure due to the small surface exposed. (The centrifugal force caused by the motion of the evaporimeter does not seem to have any effect in forcing the water through the evaporation disk).

One is reminded by this of Sworykin's experiments on the effect of wind velocities on the wet bulb thermometers, in which he found that after about seven miles an hour of wind the change was very slight and at, say twelve miles an hour, vanished entirely. From Russell's experiments we should then expect the wind to cause at least twice the amount of evaporation on the western prairies than it does over the eastern lowlands; but these wind velocities shown by the anemometers, do not show the relation of the winds that actually reach the surface of the earth where evaporation takes place, for on the prairie lands the increase of wind velocity with the height above ground is probably very slight in comparison with that of the wooded lands of the east and south, and is in fact more nearly that found on the ocean (see further along), and so the evaporating effect of these prairie winds would be several times that of the winds on forest lands. Of course, in actual observations of evaporation, the temperature, humidity, cloudiness, etc., have so much effect, that the true effect of the wind velocities is hard to determine.

SECTION V. RELATION OF LOCATION AND WIND VELOCITIES.

Taking first the Atlantic coast stations, we find that there is a remarkable agreement in the velocities of the best exposed stations. Take the values for

	Annual average m. p. h.
Block Island	14.8
Sandy Hook	14.1
Cape May	13.6
Cape Henlopen	15.8
Cape Henry	12.5
Kitty Hawk	14.8
Hatteras	14.6
Fort Macon	12.8
Mean	14.1 miles per hour.

All of these stations are either located on small islands near the coast, or on projecting peninsulas with low lands in the vicinity, and probably offer as good exposures for determining the true wind velocities unaffected by the local influences as can be well found (unless light houses or reefs are used as places for observation). The extreme difference in latitude is only 6°. On the Gulf of Mexico we find

	Annual average m. p. h.
Key West	9.8
Cedar Keys	9.2
Galveston	9.6
Indianola	12.9
Mean	10.4 miles per hour.

Here we find the mean of these velocities to be only 73 per cent. of what they are for the Atlantic coast stations. In the Gulf observations the mean of the two stations in the western part is a little greater than those in the eastern part.

For the Pacific coast, I am unable to say much, as I am unacquainted with the coast lines there, but judging from the wind velocities, those on the extreme Northwest coast and Alaska and on Cape Mendocino are the only ones to be compared with the exposed stations of the Atlantic coast; and even Mendocino ought not to be compared with the eastern Signal Service stations, but rather with the observations made at the Blue Hill Observatory near Boston. Cape Mendocino has a latitude of 41° and an elevation above the sea of 637 feet (barometer), while Blue Hill is in latitude 42° and has an elevation of 640 feet; the former has a greater angle of sea exposure however, and on this account would perhaps give higher velocities than the latter. Mendocino is the counterpart of Hatteras as regards coast contour but its much greater elevation forbids comparison of the velocities of the two places. In general, however, it would seem that the winds of the Atlantic and Pacific coasts are nearly equal, notwithstanding the fact that one is a leaward and the other a windward coast.

For the Lake stations we have:

	Annual average m. p. h.
Oswego	8.7
Buffalo	9.2
Erie	10.1
Cleveland	9.4
Toledo	8.5
Port Huron	9.6
Alpena	8.9
Mackinaw	9.8
Grand Haven	10.8
Milwaukee	10.9
Chicago	8.4
Escanaba	9.4
Marquette	8.4
Duluth	7.3
Mean	9.4

These stations are in towns of considerable size or cities, and in making comparisons with sea coast places we must choose for the latter such stations on the Atlantic coast as

	Annual average m. p. h.
Eastport	9.1
Portland	7.6
Boston	9.2
New Haven	7.6
New York	9.4
Wilmington	7.1
Charleston	7.9
Mean	8.3 miles per hour.

Such stations as San Francisco—9.3 on the Pacific coast belong to this class. These stations being so near the coast as to receive the increased velocities due to the location, without, however, having the free exposure to the full force of the ocean winds, such as we find for stations already discussed.

The Lake stations have a mean velocity of 9.4 and the Atlantic stations of 8.3, the former exceeding the latter by 13 per cent., but they are also in most cases somewhat nearer the water, so that there is probably little difference.

The velocities out upon the Lakes are probably very nearly those found on the Atlantic and Pacific oceans near the coasts.

It is very important to get an idea of the differences in wind

velocities which may exist in different good exposures for the same locality. The neighborhood of New York furnishes a complete example of this. Here are three totally different exposures. 1st. Central Park Observatory at the centre of Manhattan Island and of New York City, and having an immediate surrounding of foliage—but the anemometer is doubtless little above the roofs of the distant buildings bordering on the park. 2nd. About four miles south of this is located the Signal Service Station, at the top of a high building and with a free exposure. 3rd. About nineteen miles south of the Signal Service Station of New York is the sea coast station of Sandy Hook on a low flat point of land, and from the uniformly high velocities recorded here, it is evidently one of the best exposed stations on the coast.

We give the following table of wind velocities for these three close stations:

	J.	F.	M.	A.	M	J.	J.	A.	S.	O.	N.	D.	Year.
Central Park, 1869-78...	5.9	5.8	5.9	7.1	6.0	5.0	4.2	4.1	3.7	4.1	5.0	5.7	5.2
New York City, 1871-84.	9.9	10.9	11.6	10.0	8.8	8.0	7.7	7.5	8.7	9.4	10.1	10.2	9.4
Sandy Hook, 1874-84....	15.1	14.7	16.6	14.5	12.4	11.9	11.1	11.2	13.7	14.9	16.4	16.9	14.1

These values expressed in per cents. of the velocities at the sea coast station of Sandy Hook are:

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year.
Central Park.....	.40	.40	.36	.49	.49	.42	.38	.37	.27	.28	.30	.34	.37 per cent.
New York City...	.68	.74	.70	.69	.71	.67	.69	.67	.64	.63	.62	.60	.67 per cent.
Sandy Hook.....	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00 per cent.

The relation between two places is by no means uniform, however, for different years and months. For Sandy Hook to New York City (Sig. Serv.) the relation for several years is as follows:

Year.....	1880	1881	1882	1883	1884	1885
Ratio (S. H. ÷ N.Y.)..	1.67	1.38	1.60	2.06	1.75	1.65

Provincetown, Cape Cod, Mass., and Boston, were also thought to offer an opportunity of comparing an exposed sea coast station with a well exposed land station, but the relatively low velocities at Provincetown indicate an obstructed exposure. From the slight personal knowledge I have of the location of the town I should judge the exposure to be free on one side and somewhat

obstructed on the other. The monthly ratios of Provincetown to Boston for two years are:

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
1882.....	....	....	1.07	0.97	0.99	1.11	1.06	0.98	1.04	1.03	1.11	1 07	
1883.....	1.20	1.16	1.06	1.01	1.06	1.08	0.98	0.84	0.85	1.04	1.05	1.22	
1884.....	1.03	1.02	0.96	....	....	....	....	....	....	....	....	....	
Average P. ÷ B.	1.12	1.09	1.03	0.99	0.98	1.10	1.02	0.91	0.94	1.04	1.08	1.14	1.04

Thatcher's Island, Mass., Cambridge and Boston can, however, be compared as to location similarly to Sandy Hook, Central Park and New York. In this case, however, the Cambridge observations are estimated once a day on the scale 0 — 10 (see further on for reduction of the Cambridge observations). We have in this comparison, in miles per hour:

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
Cambridge (H. C. O.) 1882-87....	4.5	4.5	5.6	5.0	4.8	4.5	3.8	4.3	5.0	4.2	4.7	4.6	4.6
Boston, 1871-84...	9.9	10.6	11.3	10.1	8.8	7.8	7.4	7.1	8.2	9.0	10.3	10.0	9.2
Thatch.Id.1876-82.	17.2	17.8	17.2	14.1	12.2	10.4	9.5	9.1	11.7	13.1	16.0	16.8	13.8

And these reduced to percentage of Thatcher's Island give:

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year
Cambridge (H. C. O.)	.26	.25	.33	.35	.40	.43	.40	.47	.42	.32	.29	.27	.33
Boston.....	.58	.60	.66	.72	.72	75	.78	.78	.70	.69	.64	.60	.67
Thatcher's Island...	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

As the three comparison stations near New York and Boston are quite similarly located with regard to each other, it is of interest to compare the relative results. For the *year* there is a remarkable agreement as shown by the column of percentages of the ocean station. The two series of observations seem to show that on the eastern coast at least, the high, well exposed stations have about two-third the amount of wind that blows over the coast waters, and stations a few miles inland with ordinary exposure have only one-third of the ocean winds. And I incline to the opinion that stations like Cambridge and Central Park have about the same amount of wind that stations further inland would have with the same exposure. Here then we have a rough determination of the relative fractional resistance offered by land and water surfaces.

In Signal Service Note VI, Prof. Hazen finds the wind at the Lake Crib, located out in the lake three miles from Chicago, to be 1.6 times the wind at Chicago for the months April to September, 1882. Applying this factor 1.6 to the Chicago mean veloci-

ties 8.4 and we get a velocity of 13.44 for the exposed surface of the lake. This is nearly the mean value of the exposed stations on the Atlantic coast. The anemometer at the Crib was 37 feet above the lake, and the Chicago anemometer was 103 feet above ground, and perhaps 30 or 40 feet above surrounding buildings. For the summer months the Chicago wind : Lake Crib wind :: .62 : 1.00. On the eastern coast for these same months for Boston and New York, as compared with exposed ocean stations, the relation is .68 : 1.00 and .74 : 1.00 respectively.

Many cities, especially along rivers, lie in basins with the river bluffs on several sides. Such for instance, are Washington, D. C., Cincinnati and Pittsburg. The anemometers at such cities do not indicate the true wind velocities. Observations at Washington and the neighboring heights at Ft. Myer (150 or 200 feet difference in elevation) show the following relations for the year:

Washington : Ft. Myer :: 1 : 1.50, (See M. Z., Aug., 1887, page 294).

For the monthly ratios for two years there is approximately for Ft. Myer to Washington:

J.	F.	M.	A.	M.	J.	J.	A.	S.	O	N.	D.
1.5	1.3	1.5	1.5	1.5	1.2	1.3	1.4	1.6	1.7	1.8	1.6

So that it is evident that no single factor can be used for reducing observations made at any season of the year to the mean for the year, if we wish to correct observations for peculiarities of position for such localities as Washington.

The Cambridge observations used above were made at the Harvard College Observatory during the six years 1882–1887 inclusive. The wind velocity is estimated once during the forenoon of each day on the scale 0—10, the time being also noted. For the monthly values the mean of the times as well as the mean of estimations is taken. The observation is usually made at about 10 o'clock. The elevation of the ground from which the observations are made is about 74 feet above sea level, but as the agitation of the trees is taken into account in making the estimations the actual plane of observation would be about 40 feet above the ground, or about 100 or 120 feet above the sea-level, (I judge this last from my own recollections of the locality:

for, some years ago I occasionally made the meteorological observations during the absence of the regular observer). The observations are probably all made by Professor Arthur Searle, who has had many years experience as an observer, so that the accuracy is as close as can be expected by this method. Although Professor Pickering kindly communicated the mean values for each month, yet only final values are given here. The following table gives the average local time and the average wind (scales 0–10) for the different years:

CAMBRIDGE (H. C. O).

Year	1882	1883	1884	1885	1886	1887
Local time, A. M.	9.61	9 85	9.86	9.93	10.36	10.29
Wind force (0—10)	1.68	1.70	1.56	1.66	1.97	1.98

It is necessary to reduce these observations made only once a day to the daily average, but as such a reductions factor for this locality is not at hand, I have made use of the data given for Halifax and Toronto by Dr Hann in his paper, "Tagliche Period d. Wind Geschwin." Wien 1879, p. 13.

At Halifax the wind is of average velocity (1.00) at 10 A. M.; at 9.5 h. it is .97; at 10.5 h. it is 1.06 of the average. Therefore, from this, at Cambridge (H. C. O.) the corrected average wind force is

Year	1882	1883	1884	1885	1886	1887
Average wind force	1.73	1.72	1.58	1 66	1.85	1.88

At Toronto the average wind velocity occurs at 8.1 h., A. M., and at 10.0 h. the amount of wind is 1.21 of the average. So that by means of the Toronto correction the averages for Cambridge are

Year	1882	1883	1884	1885	1886	1887
Average wind force	1.44	1.42	1.30	1.38	1.60	1.61

It is difficult to decide which of these more nearly represents the actual conditions at Cambridge so the mean of the two has been taken. We have then for Cambridge,

Year	1882	1883	1884	1885	1886	1887	mean
Average force (0—10)	1.58	1.57	1.44	1.52	1.72	1.74	—
Average velocity m. p. h.	4.6	4.5	3.9	4.3	5.3	5.4	4.7

the time of occurrence of average velocity being about 9 h. A. M.

The reduction from scale 0–10 to miles per hour is made by means of the table introduced by Prof. Abbe in the Interna-

tional Bulletin of the Signal Service in which the following relations are assumed:

Scale No. (0-10)	0	1	2	3	4	5
Miles per hour	0	2.2	6.8	11.3	18.0	27.0

Incidental to this discussion I find that the combination of tri-daily observations of wind velocities $\frac{1}{3}$ (7+3+11) gives for Nukuss, w 102 per cent., s 99 per cent.; for Rome, w 100 per cent., s 108 per cent.; for Toronto, 101 per cent.; for Halifax, 101 per cent.; for Oxford, 101 per cent.; for Calcutta, 102 per cent.; and for Zi-ka-wei, 101 per cent. of the averages, obtained from hourly observations, (w standing for winter, s for summer.)

It would seem from this that near the ground, at least, the winds at Cambridge were greater for 1886 and 1887 than during the preceding years, and consequently we cannot say positively that all of the late increase in the Boston wind velocities is due to the change in the Boston Anemometer in 1884. An anemometer must be mounted in the old place and the two compared directly before this question can be settled.

The following are the monthly means for the six years at Cambridge expressed on the scale 0–10.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1.73	1.73	1.97	1.85	1.80	1.73	1.57	1.70	1.85	1.68	1.77	1.75

The average time of observation is a little after 10 o'clock, and taking the average between Toronto and Halifax again, we find that these values are about 113 per cent. of what the average values probably are. (I am obliged in this case to apply the annual correction to each month as the *monthly* corrections are not available, so that here we have a source of error.) We must then multiply these just found values by 0.9 in order to get approximately mean monthly values.

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
1.56	1.56	1.77	1.66	1.62	1.56	1.41	1.53	1.66	1.51	1.59	1.58

Reducing these to miles per hour by Abbe's table mentioned above, we get

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Year.
4.5	4.5	5.6	5.0	4.8	4.5	3.8	4.3	5.0	4.2	4.7	4.6	4.6

as used in the above comparison with Boston.

[TO BE CONTINUED.]

TORNADOES IN ARKANSAS.

STATE TORNADO CHARTS.—ARKANSAS.

By LIEUT. JNO. P. FINLEY, SIGNAL SERVICE, U. S. A.

TABLE I.—*Tornadoes in Arkansas.*

Period of observation, 49 years,—1840–1888.
Total number of storms,—53.
Year of greatest frequency, 1883,—12 storms.
Average yearly frequency,—3.5 storms.
Year in past ten (10) years, no report of storms, 1885.
Month of greatest frequency, April and May,—16 storms each.
Day of greatest frequency, April 18,—5 storms.
Hour of greatest frequency, 5 to 6 P. M. and 6 to 7 P. M.
Months without storms,—February, August and December.
Prevailing direction of storm movement NE.
Region of maximum storm frequency, central and northwest portions.

TABLE II.—*A Chronological Table showing the location, date and time of occurrence and general character of formation and movement of Tornadoes in the State of Arkansas, for a period of 49 years, from 1840 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Pulaski	June 6.	1840	1:30 a. m.	.....	.....	.....
Hempstead	July 28.	1853	5 p. m.	NE.	Funnel.	180.
Johnson	.....	1856	.....	E	.....	5,280.
Clark	April 27.	1856	Afternoon.	NE.	Funnel.	1,200.
Izard	May —	1867	.....	NE.	.....	.....
Hempstead	March 12	1875	5 p. m.	NE.	Funnel.	300.
Hempstead	January 26.	1878	Sunset.	NE.	"	75 to 300.
Sebastian	June 27.	1879	Afternoon.	SSE.	.....	.....
Crawford	November 8.	1879	3 p. m.	NE.	Funnel.	1,200 to 1,500.
Yell	April 18.	1880	8 p. m.	NE.	.....	.....
Johnson	April 25.	1880	6:15 p. m.	NE.	Funnel.	.....
White	April 18.	1880	5 p. m.	NE.	.....	1 200 to 1 500.
Washington	"	1880	8:30 p. m.	NE.	Funnel.	90.
Franklin	"	1880	6:40 p. m.	NE	"	.....
Carroll	"	1880	Afternoon.	NE.	.....	.....
Randolph	November 25.	1880	Evening.	NE.	Funnel.	.....
Prairie, Monroe, Lee and St. Francis	April 12.	1881	2 p. m.	NE.	"	.....
Newton, Searcy and Marion	May —.	1882	.....	NE.	.....	.....
Fulton	May 8.	1882	.....	SE.	.....	.....
Montgomery	"	1882	5:30 p. m.	N 30° E.	Funnel.	1,800 to 2,400.
Benton	"	1882	Evening.	NE.	.....	450 to 900.
Crawford	July 3	1882	.....	.....	.....	.....
Garland, Saline and Pulaski	April 5.	1883	8 p. m.	N 60° E.	Funnel.	2,640.
Saline	April 12.	1883	Night.	NE.	"	.....
Franklin	April 13.	1883	11:35 p. m.	NE.	"	1,320.
Johnson	May 18.	1883	.....	NE.	.....	.....
Faulkner	April 14.	1883	3:15 p. m.	NE.	.....	900.
LaFayette	April 28.	1883	2 p. m.	S.	Hour-glass.	.....
Franklin	May 18.	1883	About 5:30 p. m.	NE.	.....	.....
Baxter and Fulton	"	1883	10 p. m.	ENE.	Funnel.	2,640.
Jefferson	July 15.	1883	4:40 p. m.	.....	"	.....
Franklin, Johnson, Pope, Searcy, Stone and Izard	October —.	1883	About 6 p. m.	E 30° N.	.....	.....
Izard, Sharp and Clay	November 5.	1883	5 p. m.	E.	.....	.....
White	November 21	1883	3:15 a. m.	NE.	Funnel.	1,320.
Sebastian	May 5.	1884	.....	.....	.....	.....
Johnson	July 27.	1884	8:20 p. m.	SE.	.....	.....
	November 22.	1884	Night.	NE.	.....	3 960.

TABLE II.—*Concluded.*

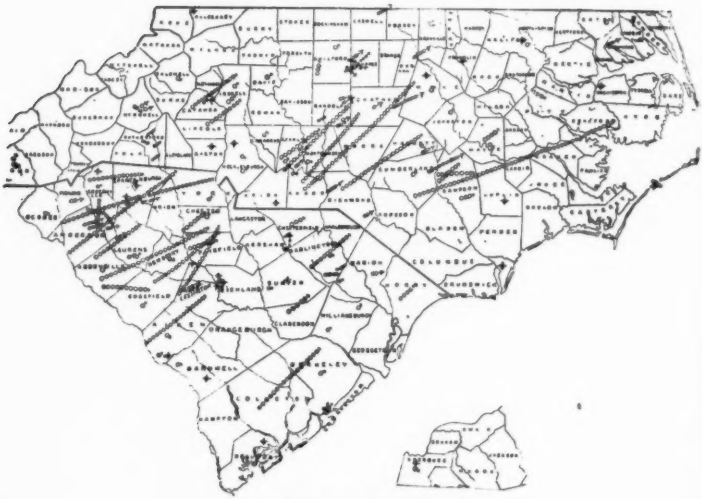
County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Johnson	November —.	1884	.....	NE.	.....	2,640.
Phillips	March 29.	1886	2 p. m.	NE.	.....	.....
Phillips	"	1886	4:30 p. m.	E.	Funnel.	900 to 1 320.
Sebastian	April 25.	1886	7 p. m.	NE.	.....	.....
Crittenden	May 6.	1886	4 p. m.	Easterly	Funnel.	5 280 to 10,000.
Johnson	April 29.	1886	9 p. m.	E.	.....	.....
Johnson	April 22.	1887	6:30 a. m.	ENE.	Funnel.	300 to 900.
Johnson	May 10.	1887	4:30 p. m.	NE.	"	Narrow.
Johnson	"	1887	"	NE.	"	300 to 1,320.
Boone	June 4.	1888	Evening.	NE.	.....	Narrow.
Miller	May 3.	1888	Afternoon.	NE.	Funnel.	450.
Onachita	"	1888	Night.	NE.	.....	600 to 1,320.
Johnson	May 24.	1888	Afternoon.	NE.	Funnel.	1,320.
Washington	May 26.	1888	7 p. m.	NE.	"	1,320.
Crawford	"	1888	Afternoon.	NE.	.....	Narrow.
Washington	June 2.	1888	Afternoon.	NE.	Funnel.	1,320.
Fulton	September 21.	1888				

TABLE III.—*Relative frequency of Tornadoes by months and days, for Arkansas.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	26	1	1
March	12 and (29)^{2}	2	3
April	5, (12)^{2}, 13, 14, (18)^{5}, 22, (25)^{2}, 27, 28 and 29	10	16
May	(3)^{2}, 5, 6, (8)^{3}, 10, (18)^{3}, 24, (26)^{2} and (—)^{2}	8	16
June	2, 4, 6 and 27	4	4
July	3, 15, 27 and 28	4	4
September	21	1	1
October	(—)	0	1
November	5, 8, 21, 22, 25 and (—)	5	6
Blank (—)	(—)	0	1
Total		35	53

NOTE.—The blank (—) signifies date missing.



TORNADOES IN THE CAROLINAS.

STATE TORNADO CHARTS.—NORTH CAROLINA.

By LIEUT. JNO. P. FINLEY, Signal Service, U. S. A.

TABLE I.—*Tornadoes in North Carolina.*

Period of observation, 63 years, 1826–1888.
Total number of storms,—80.
Year of greatest frequency, 1884,—15 storms.
Average yearly frequency,—3.1 storms.
Year in past ten (10) years, no report of storms,—none.
Month of greatest frequency, April,—15 storms.
Day of greatest frequency, February 19th.
Hour of greatest frequency, 3 to 5 P. M.
Months without storms,—none.
Prevailing direction of storm movement, NE.
Region of maximum storm frequency, central portion.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of North Carolina for a period of 63 years, from 1826 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Rowan	October 20.	1826	6 p. m.	NE.	Funnel.	300.
Gates	August 25.	1829	.....	NE.	"	.....
.....	October 12.	1833	.....	.....	.....	.....
Harnett	.....	1834	.....	SE.	.....	.....
Guilford	April 7.	1837	.....	N.	.....	.....
Alamance	April 10.	1841	11 a. m.	SE.	Funnel.	600.
Halifax	June 10.	1850	.....	.....	.....	2,640.
Halifax	August 27.	1851	9:15 p. m.	N. 10 E.	.....	.....
Pitt	October —.	1854	3:30 p. m.	SE.	.....	150 to 300.
Iredell	April 20.	1871	Afternoon.	NE.	Funnel.	900.
Mecklenburgh	April 18.	1872	"	.....	"	.....
Mecklenburgh	September 8.	1872	5 p. m.	SE.	.....	.....
Cumberland, Sampson, Duplin and Craven	April 2.	1873	8 p. m.	NE.	.....	2,500.
Mecklenburgh	March 20.	1875	3:50 p. m.	ENE	Funnel.	450.
Iredell	"	1875	11 a. m.	NE.	"	.....
Franklin	"	1875	.....	.....	.....	1,200.
Cabarrus	"	1875	.....	.....	.....	.....
Gaston	"	1875	4:15 p. m.	NE.	Funnel.	600
Sampson	"	1875	3 p. m.	NE.	"	.....
Caldwell	"	1875	5 p. m.	E.	"	2,640.
Alleghany	June 25.	1876	3:45 p. m.	SE.	.....	.....
New Hanover	September 13	1876	.....	.....	.....	.....
Wake	December 29.	1876	.....	.....	.....	.....
Carteret	April 29.	1877	.....	NE.	.....	.....
Cumberland	July 3.	1877	3 p. m.	.....	.....	.....
Washington	February 8	1878	7 a. m.	NE.	Funnel.	.....
Wayne	August 2.	1878	Afternoon.	.....	.....	.....
Wayne	September 12.	1878	7 a. m.	NE.	Funnel.	300.
Guilford	"	1878	Afternoon.	SE.	.....	200 to 500.
Randolph	April 3.	1879	"	NE.	.. ..	.....
Carteret	June 30.	1880	10 p. m.	SE.	Funnel.	1,320 to 2,640.
Macon	July 28.	1880	5:30 p. m.	SE.	"	60 to 90.
Duplin	August 13.	1881	Afternoon.	NE.	.....	5,000 to 6,000.
Catawba	November 6.	1881	12 m.	.....	.....	.....
Stanly	April —.	1882	.....	.....	.....	90 to 120.
Sampson	February 19.	1883	11 p. m.	NE.	Funnel.	1,320.
Cherokee	April 23.	1883	7 a. m.	.....	.....	450.
	December 24.	1883	8:30 p. m.	E by S.	Funnel.	.....

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Anson	February 19.	1884	8 p. m.	N 55° E.	Funnel.	900 to 1,320.
Stanly	"	1884	8 p. m.	NE.	"	1,200.
Union, Stanly, Montgomery and Randolph	"	1884	7 p. m.	NE.	"	300 to 2,640.
Stanly	"	1884	7 p. m.	NE.	"	1,200.
Richmond and Harnett	"	1884	10 p. m.	N 50° E.	"	900 to 2,640.
Anson, Richmond and Montgomery	"	1884	8:30 p. m.	NE.	Cylindrical.	900 to 1,320.
Lincoln and Iredell	March 25.	1884	5 p. m.	NE.	Funnel.	1,320.
Montgomery	"	1884	11 p. m.	E	"	.....
Johnston	"	1884	11:30 p. m.	NE.	"	300.
Stanly and Montgomery	"	1884	11 p. m.	NE.	"	225.
Catawba	"	1884	5 p. m.	ENE.	"	300 to 1,500.
Macon	"	1884	6:45 p. m.	E 6° S.	"	900.
Rutherford	March 27.	1884	Midnight.	E.	"	2,640.
Union	April 14.	1884	5 p. m.	.....	....	.....
Sampson	December 22.	1884	5:30 p. m.	NE.	.....	3,960.
Cherokee	May 1.	1885	11:45 a. m.	.....	Funnel.	.....
Anson	May 27.	1885	6:30 p. m.	E.	"	.....
Rutherford	April 15.	1885	Evening.	NE.	"	.....
Rutherford	"	1885	Afternoon.	NE.	....	.....
Orange and Alamance	May 12.	1885	About 3:30 p. m.	Easterly.	....	2,640.
Dare	July 6.	1886	6 p. m.	.....	Waterspout.	.....
Dare	October 1.	1886	Afternoon.	Easterly.	Funnel.	.....
Alamance	January 24.	1887	Morning.	E	"	1,320.
Catawba	January 25.	1887	4 a. m.	NE.	.....	600.
Chatham	April 18	1887	Noon.	NE.	Funnel.	1,200.
Randolph	April 28.	1887	4:30 p. m.	E	"	Narrow.
Stanly	May 6.	1887	3:30 p. m.	NE.	.....	"
Alamance	May 25.	1887	3:30 p. m.	NE.	Funnel.	2,640.
Randolph	June 1.	1887	4 p. m.	NE.	"	2,640.
Rutherford	"	1887	Evening.	SE.	.....	300.
Perquimans	June 2.	1887	9 p. m.	NE.	Funnel.	300 to 450.
McDowell	June 13.	1887	5 p. m.	NE.	"	Narrow.
Alamance	June 18.	1887	3 p. m.	SE.	"	5,280.
Chatham and Wake	April 25.	1887	Noon.	NE.	"	900 to 1,200.
Granville and Durham	May 19.	1888	Afternoon.	NE.	"	2,640.
Caswell	June 2.	1888	4 a. m.	NE.	....	1,500.
Wade, Cumberland and Sampson	June 5.	1888	6:30 p. m.	NE.	Funnel.	2,640.
Harnett	"	1888	7 p. m.	Easterly.	.....	1,320.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Richmond	June 28.	1888	2:30 p. m.	NE.	Funnel.	Narrow.
Richmond	"	1888	3 p. m.	Easterly.	"	600 to 1,200.
Randolph	July 4.	1888	2 p. m	Easterly.	"	1,320.
Randolph	August 1.	1888	3 p. m.	NE.	"	2,640.
McDowell	August 4.	1888	10 a. m.	SE.	.....	1,320.
McDowell	"	1888	3 p m.	NE.	Funnel.	900 to 1,000.

TABLE III.—*Relative frequency of Tornadoes by months and days, for North Carolina.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	24 and 25	2	2
February	8 and $(19)^2$	2	8
March	$(20)^6$, $(25)^6$ and 27	3	13
April	2, 3, 7, 10, 14, $(15)^2$, $(18)^2$, 20, 23, 25, 28, 29 and (—)	12	15
May	1, 6, 12, 19, 25 and 27	6	6
June	$(1)^2$, $(2)^2$, $(5)^2$, 10, 13, 18, 25, $(28)^2$ and 30	9	13
July	3, 4, 6 and 28	4	4
August	1, 2, $(4)^2$, 25 and 27	5	6
September	8, $(12)^2$ and 13	3	4
October	1, 12, 20 and (—)	4	4
November	6	1	1
December	22, 24 and 29	3	3
(—) Blank	(—)	1	1
Total		55	80

NOTE.—The blank (—) signifies date missing.

TORNADOES IN DAKOTA.

STATE TORNADO CHARTS.—DAKOTA.

By LIEUT. JNO. P. FINLEY, Signal Service, U. S. A.

Table I.—*Tornadoes in Dakota.*

Period of observation, 14 years, 1875-1888.
Total number of storms,—67.
Year of greatest frequency, 1888,—16 storms.
Average yearly frequency,—5.6 storms.
Year in past (10) ten years, no report of storms,—1882.
Month of greatest frequency, July,—22 storms.
Day of greatest frequency, August 15th,—6 storms.
Hour of greatest frequency, 6 to 7 P. M.
Months without storms, January, February, October, November and December.
Prevailing direction of storm movement, NE. and SE.
Region of maximum storm frequency, southeast portion.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the Territory of Dakota for a period of 14 years, from 1875 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Morton	March 15.	1875	.....	.....	.....	.....
Buford	March 24.	1875	.....	.....	.....	.....
Yankton	May 20.	1876	11:50 a. m.	NE.	.....	.....
Hutchinson	April 17.	1878	Afternoon.	SE.	.....	.....
Cass	August 26.	1878	6:10 p. m.	SE.	.....	1,000 to 1,500
Hamlin	July 2.	1879	5:30 p. m.	NE.	.....	3,000 to 5,000.
Davison	May 25.	1880	7:50 p. m.	NE.	Funnel.	.....
Cass	August 18.	1880	.....	.....	.....	.....
Lawrence	June 6.	1881	Afternoon.	NE.	Funnel.	.....
Grant	July 11.	1881	5:50 p. m.	NE.	"	.....
Brookings	July 13.	1883	6:30 p. m	E 20° N.	"	20 to 100.
Clark	July 14.	1883	6:30 p. m.	SE.	"	5,000.
Spink	July 18.	1883	7:30 a. m.	.....	.....	1,320.
Brookings	July 19.	1883	10 a. m.	E.	.....	.....
Lawrence	July 5.	1884	4 p. m	.....	Funnel.	3,960
Minnehaha	July 21.	1884	.....	.....	.....	.....
Kingsbury	"	1884	2 p. m.	ESE.	Funnel.	.....
Minnehaha	"	1884	3:05 p. m.	SE.	"	.....
Moody	"	1884	1:30 p. m.	E 30° S.	"	.....
Miner, Lake and Minnehaha	July 28.	1884	3 p. m.	SE.	"	.....
Beadle, Sanborn, Miner, McCook and Hanson	August 28.	1884	4 p. m.	SE.	"	.....
Beadle	September 1.	1884	Daylight.	S-E.	"	250
Clay	September 9.	1884	5 p. m.	NE.	"	.....
Lawrence	June 11.	1885	1:28 p. m.	SE.	Cylindrical.	165.
Jerauld	June 12.	1885	5:25 p. m.	SE.	Balloon.	.....
Hughes, Hyde and Hand	July 15.	1885	6:40 p. m.	SE.	Funnel.	500.
Yankton	September 11.	1885	7 p. m.	E 20° S.	Inverted cone.	.....
Clay	"	1885	8 p. m.	ESE.	Funnel.	1,320.
Stutsman	April 14.	1886	3:30 p. m	NE.	"	.....
Benson	"	1886	p. m.	Easterly.	.....	.....
Ramsey	"	1886	Afternoon.	NNE.	Funnel.	40.
Barnes	June 11.	1886	Afternoon.	NE.	.....	.....
Cass	"	1886	7 p. m.	NE.	.....	.....
La Moure	"	1886	Evening.	NE.	Funnel.	.....
Nelson	July 23.	1886	4:30 p. m.	NE.	"	2,640 to 5,280.
Brown	August 10.	1886	Night.	NE.	.....	.....
Spink	"	1886	Midnight.	Easterly.	.....	.....

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Day	August 15.	1886	6:30 p. m.	ESE.	Funnel.	2,640 to 5,280.
Turner	"	1886	6 p. m.	Easterly.	.....	.....
La Moure	"	1886	5 p. m.	ENE.	Funnel.	.....
Richland	"	1886	Evening.	NE.	"	2 640 to 5,280.
Sargent	"	1886	6:30 p. m.	ESE.	"	2 640 to 5,280.
Brookings	"	1886	7:30 p. m.	SE.	"	5,280.
Ransom	May 23.	1887	11:30 a. m.	SE.	"	Narrow.
Stutsman	June 6.	1887	5 p. m.	NE.	"	Narrow.
Beadle	June 7.	1887	3:10 p. m.	E.	"	5 280.
Grand Forks	June 16.	1887	3:22 p. m.	E.	"	5,280.
Sully	July 10.	1887	4 p. m.	NE.	"	Narrow.
Sully	"	1887	4 p. m.	SE.	"	2 640.
Sully	"	1887	3:20 p. m.	SE.	"	1 320.
Hughes	"	1887	6 p. m.	SE	"	Narrow.
Boreman	June 9.	1888	2 a. m.	E	.....	Narrow.
Boreman	June 13.	1888	Evening.	ESE.	Funnel.	2 640.
Sargent	"	1888	Night.	SE.	.....	2,640.
Sully	July 1.	1888	9:30 p. m.	NE.	.....	1,320 to 2,640.
McCook	July 6	1888	Afternoon.	Easterly.	.....	2,640.
Potter	July 26.	1888	7:15 p. m.	NE.	Funnel.	2,640.
Sully	July 28.	1888	9 p. m.	NE.	.....	5,280.
Kingsbury	August 4	1888	5:30 p. m.	SE.	Funnel.	100 to 200.
Beadle	"	1888	3:30 p. m.	NE.	"	2,640.
Beadle	"	1888	6 p. m.	SE.	"	1 320 to 2,640.
Todd	August 5.	1888	7 p. m.	NE.	"	50 to 100.
Douglas	"	1888	6:30 p. m.	NE.	"	2,640.
Bon Homme	"	1888	6 p. m.	NE.	"	2,640.
Lake	August 7.	1888	3 p. m.	NE.	"	1,320.
Kingsbury	August 28.	1888	2 p. m.	NE.	"	1,320.
Kingsbury	August 30.	1888	Afternoon.	NE.	"	2,640.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Dakota.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
March	15 and 24	2	2
April	(14)[3] and 17	2	4
May	20, 23 and 25	3	3
June	(6)[2], 7, 9, (11)[4], 12, (13)[2] and 16	7	12
July	1, 2, 5, 6, (10)[4], 11, 13, 14, 15, 18, 19, (21)[4], 23, 26 and (28)[2]	15	22
August	(4)[3], (5)[3], 7, (10)[2], (15)[6], 18, 26, (28)[2] and 30	9	20
September	1, 9 and (11)[2]	3	4
Total		41	67

CORRESPONDENCE.

A DEVICE FOR FACILITATING THE READING OF ELECTRICAL ANEMOGRAPH RECORDS.

To the Editors:—In the electrical recording anemometers, such as those used by the U. S. Signal Service, and described in their publications, there are ten pins on the outer dial wheel which is turned by the revolutions of the anemometer cups. The adjustment is such that one of these pins comes in contact with a spring every time a mile of wind has passed. An electric current is thus closed and passing through an electro-magnet, to the armature of which a pencil is attached, makes a mark on a chronograph for each mile of wind. Such an anemograph has been in use at Blue Hill observatory for several years; and in order to more easily obtain the total wind movement for an hour or for a day, the writer connected two of the pins in the anemometer dial wheel by a stiff piece of metal; so that at the end of each ten miles the electrical circuit is kept closed until an entire mile of wind has passed, and the two connecting pins have moved out of contact with the spring. In this way, at the end of every ten miles of wind a broad mark is made on the chronograph. The beginning and end of this mark is counted as the termination of a mile of wind, and thus each mile of wind can be counted as without the attachment. This has been in regular operation at Blue Hill observatory since the first of November 1887, and has proved a great convenience in summing up large daily or hourly wind movements. Prof. Marvin of the U. S. Signal Service, who visited the observatory, was so much pleased with it that it has been introduced into the signal service anemographs. It is easily applied and would no doubt prove a convenience to other observers who use these anemographs, and who live in places where there is considerable wind movement.

H. Helm Clayton.

Blue Hill Observatory, October 18, 1889.

CURRENT NOTES.

ON CERTAIN THEORIES OF ATMOSPHERIC ELECTRICITY.*—The writer examines at some length the different theories proposed to account for the origin of the electricity of the atmosphere and shows that they are all more or less opposed by certain observed phenomena. He passes then to his theory of unipolar induction and proves that this force will result, at high altitudes, in an augmented potential of the air, agreeing with what we ordinarily find. A. M.

PROPOSED WEATHER SERVICE IN HONDURAS.—From the newspapers we learn that Senor Cecil, director general of telegraphs in the republic of Honduras, sailed Oct. 2nd for home, having spent some four months in New Orleans and other portions of the United States. He proposes to establish a signal service station at Puerto Cortes, on the north coast of Spanish Honduras, to coöperate with the service in the United States. He will be furnished with a complete set of instruments by the New Orleans office. This, it is hoped, is only the beginning of a movement which will in a few years result in the establishment of a line of signal service stations all along the shores of Mexico and Central America, which is now, in so far as the Signal Service is concerned, a complete *terra incognita*. Mr. Cecil hopes to get appropriations from his government sufficient to purchase instruments for stations throughout his country. All important weather news will be cabled direct to the New Orleans office, thus insuring a source of information concerning the dangerous cyclonical disturbances which originate in the tropical regions.

ON THE THEORY OF HAIL.†—Mr. Tomlinson begins his article with some references in detail, showing the ideas and opinions held by the older physicists and writers on meteorology as to the formation of hail. Kämtz for example, included all kinds

* E. Edlund. *Annales de Chemie et de Physique*, Vol. XIII, 1888, p. 145.

†Charles Tomlinson, F. R. S., &c., *Phil. Mag.*, Sept. 1889.

of hail under electrical phenomena, but honestly stated that many facts were opposed to such a classification. In such a belief, we find in part an explanation of the introduction and extensive use of the *paragrêle* or hail conductor, especially in France. It was believed that the formation of hail was due to a sudden disturbance of the electrical equilibrium of the clouds, hence if the electric fluid (?) could be quietly drawn off, there could be no hail. It did not take long for a hard matter-of-fact experience to upset this reasoning. Volta's theory of the formation of hail is given at some length, with the critical objection to it, that these storms may occur at any hour of the night as well as the day. Peltier's theory, for the most part, a modification only of Volta's, is also commented on. But the tendency of modern investigation is to find the efficient cause for the formation of hail rather in the whirlings of the air itself than in electricity. Ferrel's theory supposes that the plane of zero temperatures has the water vapor condensed below it into rain, and above it, into snow. Now, ascending currents may carry up the rain drops and if suspended for a while they become frozen. "They may then become suspended near the base of the snow-cloud and increase in size by the rain which is carried up into this region, coming into contact with them before it has had time to freeze." Some very interesting sketches of hail stones observed by the writer at Leipsic, are given. Some of the stones were very large, and weighed as much as 5 oz. "A curious example of the force of the icy bullets was shown in the destruction of the new cane bottom of a chair. . . Zinc water pipes were shot through and in one case a pipe was flattened."

We would urge upon readers of the JOURNAL, the importance of observations on the size, weight and character of hail-stones, and perhaps in some simple way the making of measurements on the penetrating power, if the term is allowable, of these stones. A. M.

NOTES.—Professor Ferrel, finds in a paper in the July number of the *American Journal of Science*, that the relation of thermal

radiation to temperature, even in ranges of temperature over which experiments have extended, is not satisfactorily expressed by either of the usual formulas,—Dulong and Pettit's or Stefan's. A modification of the latter, expresses the observed facts rather better, but in any case it is entirely unsafe to extend any of the forms to such temperatures as must prevail on the sun.——As to the hourly progress of the barometer F. C. Bayard, Esq., in the *Quar. Journal of the Royal Met. Soc.*, from observations of the nine principal observatories in the British Isles, finds that each station has its own peculiarities, even at stations only a few miles apart. In general the curves for inland places are smoother than those for stations near the sea coast. The curves grow more irregular for stations to the westward, and from southeast to northwest the general tendency of the curve is to become flatter, with a less diurnal range. He also finds that a third small maximum, between 2 A. M. and 3 A. M., tends to disappear as we proceed northward, with a lessened diurnal range. ——Rain gathers an appreciable quantity of impurities during its fall, and the quantity depends more on the number of showers than on the total rainfall. At Lincoln, New Zealand, Geo. Gray, Esq., lecturer in the School of Agriculture, has pursued the systematic analysis of rain water for nearly five years. He finds that an acre of land at Lincoln receives annually (in 28.9 inches of rain) about 179 lbs. of dissolved solids; of these, 60.5 lbs. consist of chlorine, 15 lbs. of sulphuric anhydride, and a little over 2 lbs. of nitrogen, about one-half as nitric acid, the remainder in ammonium compounds and organic matter. The amount of chlorine is unusually large, but Lincoln is not far from the sea. —(*Proc. Austr. Assoc. for the Adv. of Sci.*)

The St. Thomas–Hatteras Hurricane of Sept. 3–12, 1889. —This is the storm that caused so much damage on the Maryland and New Jersey coast. The damage on the coast was doubtless greater because of the coincidence of the high seas of the storm with the high tides accompanying the full moon of September 9th falling near the perigee of September 5th. A curious fact is the occurrence of several small earthquakes over

the states at about the same time and also an unusual activity of the geysers of the Yellowstone Valley. The earthquakes are a little more apt to occur at about the time of full moon and perigee; the coincidence of the geyser activity may have been accidental.

The Hydrographic Office of the Navy Department has published a very interesting series of 10 charts showing the position of the storms, and the state of the meteorological elements over the Bay of North America and the eastern United States for each day of the storm. From them it appears that two storm centers flowed together off Cape Hatteras on the 8th and passed northeastward at a very deliberate speed. We sincerely regret that we can not reprint these charts on which the progress of the storms is garphically represented. We will, however, reproduce the condensed daily statement which accompanies the charts.

Sept. 3.—A hurricane of great intensity is passing close to the northward of St. Thomas, moving about WNW. Lowest barometer at St. Thomas during the day, 28.97. Steepest observed barometric gradient (between St. Thomas and Puerto Rico), .75 inch in 65 miles. The cyclone is a large one, and of terrific energy,—an enormous whirlwind more than 500 miles in diameter, with a central calm area about 16 miles in diameter. It was experienced with destructive violence amongst the Windward Islands, from Martinique to Barbuda, on the 2d, and the vortex passed over St. Christopher's about midnight, the central calm lasting from 10:15 P. M. of the 2d till 12:45 A. M. of the 3d. There are evidences of another hurricane about 1,000 miles eastward of the first, moving about WNW.

Sept. 4.—The hurricane is central north of Puerto Rico, where strong northerly, westerly, and southerly gales are experienced, but not of full hurricane force. During the forenoon its massive, towering cloud-bank is clearly visible from Turk's Island, 300 miles away, causing great alarm till it is seen to be moving well to the northward of the island. A violent storm at Santo Domingo this afternoon seems to be either an offshoot from the cyclone or the effect of another storm crossing the island to join the great hurricane—possibly a storm that was felt at Curaçao the previous day. The second hurricane has continued its motion toward WNW and its present position is clearly indicated about the eastern limits of the Chart.

Sept. 5.—The hurricane is moving rather slowly along a northwesterly course, toward Hatteras. The enormous seas started by the great whirl-

wind during its progress thus far have overspread almost the entire western half of the Atlantic; heavy northeasterly swell at Jamaica and through the Windward Channel; northeasterly and easterly, all along the Bahama Islands and northern Florida; very heavy surf at Bermuda; long rolling swell from SSE, off Hatteras, perceptible as early as the 2d and increasing daily; long, low southerly swell off Nantucket as early as the 4th, when the storm-center was 1,300 miles away. The second hurricane is moving northwestward, and is beginning to recurve about 600 miles SE from Bermuda.

Sept. 6.—The concentric isobars on the Chart show that the hurricane is now central about midway between Bermuda and Eastern Cuba, with barometric pressure at the center probably below 28.40. All the characteristics of a tropical cyclone are still exhibited, and to a marked degree: storm area noticeably circular in outline; very steep gradients and enormous wind velocities near the center; sudden shifts of the wind in terrific squalls; heavy driving rain mingled with foam caught up from the crests of the waves; sky of inky blackness, with masses of flying scud so low as to touch the masts. Close by, in front, and on either side, calm, sultry, hazy weather, with a tremendous swell rolling in from the direction of the distant but massive cloud-bank of the hurricane. A long ridge of high pressure is building up to the northward of the hurricanes

Sept. 7.—The hurricane continues its slow but steady march toward Hatteras. Yesterday morning the observer at Santiago de Cuba reported the cyclone recurving. This morning the meteorologist at Havana, 900 miles away, reports the cyclone's movements, guided by the motions of the upper clouds,—the cirrus veil that overspreads the entire sky with a thick haze, and the long feathery plumes of cirrus cloud that are faintly visible above it, radiating from the distant storm. The influence of the great hurricane begins to be felt along the outer edge of the Gulf Stream, below Hatteras. A heavy surf is rolling in on the coast all the way from Cape Florida to Block Island, and the long southerly swell has reached beyond Sable Island to Cape Breton. The second hurricane is moving northeastward, and a ridge of high pressure is extending southward between the two.

Sept. 8.—The hurricane is central about the axis of the Gulf Stream, off Hatteras. The area of high barometer in advance is retarding its northward progress, and preventing it from recurving to the northeastward. The heavy surf and the increased height of the tides, due to the storm-wave of the hurricane, begin to attract general attention and to cause damage along the low-lying portions of the coast between Norfolk and Newport; warm, moist ocean air is being driven in over the cold inshore current, and dense fogs are encountered off the coast north of the 35th parallel. The storm is losing a little of its tropical intensity,

but its area is increasing and winds of hurricane force are raging over a vast area between Hatteras and Bermuda.

Sept. 9.—The storm is still raging with great violence between Nantucket, Hatteras and Bermuda. Tremendous seas and tides are driving in on the coast. It is blowing with hurricane force close in shore near Hatteras. The storm centre is still moving northward, but more slowly, and the great area of high barometer into which the hurricane has forced its way, stands fast, the pressure rising to 30.30, over the Gulf of St. Lawrence and the isobar of 30.00 reaching south on either side well down toward the tropics. To the northwestward, northward, and northeastward close to the outer limits of the great whirlwind, warm, sultry weather prevails, with calms or light, variable winds, hazy weather and barometer above the normal.

Sept. 10.—The hurricane seems to be gathering all its strength for a last desperate struggle to force its way along its normal track to the northeast. The wind-arrows plotted on the Chart illustrate very graphically the marked circular character of the great whirlwind. The storm-wave, or general elevation of the oceanic surface caused by the in-rushing and whirling winds, and the reduced barometric pressure (acting as a partial vacuum), bank up the water in the bight of the coast about Sandy Hook and cause the greatest floods on record at many places along the eastern coast of Nery Jersey and the southern shore of Long Island.

Sept. 11.—The barometric pressure at the storm centre has increased noticeably. The low area is filling up, and the barometric gradients are very much less steep. Very few winds of full hurricane force are reported. The storm-centre has moved in toward shore, however, and stormy winds are still felt along the coast. The clouds are breaking away in places, and the cyclonic circulation is no longer so well marked. The warm waters of the Gulf Stream have been driven in toward the coast off Block Island by the long-continued and furious southeasterly gales to the right of the storm track, and mingling with the cold inshore current, cause dense fogs, and squally, unsettled weather.

Sept. 12.—The great hurricane has blown itself out, and although a few reports still give a force of wind as high as 10 of Beaufort's scale, the storm has practically ended. Its remnants drift inland during the 13th and 14th, with cloudy, rainy weather in eastern Virginia and Maryland. It leaves a mountainous cross-sea that lasts for several days, a coast-line strewn with wreckage, and already some twenty additions have been made to the list of derelicts and drifting wrecks whose positions are plotted on the Pilot Chart as a caution to navigators. How many vessels it wrecked at sea can never be fully known, but its entire track is marked by wrecks and wreckage.

AMERICAN METEOROLOGICAL JOURNAL.

AN ILLUSTRATED MONTHLY

DEVOTED TO SCIENTIFIC METEOROLOGY AND ALLIED BRANCHES OF STUDY.

THE AMERICAN METEOROLOGICAL JOURNAL CO., Publishers and Proprietors,
Ann Arbor, Michigan.

M. W. HARRINGTON,
Director of the Astronomical Observatory, Ann Arbor, Michigan,
A. LAWRENCE ROTCH,
Proprietor of the Blue Hill Meteorological Observatory, Massachusetts,
W. J. HERDMAN, PH. B., M. D.,
University of Michigan.
Editors.

KITTREDGE & MORAN, Managers.

PRICE,—IN THE UNITED STATES, - - - - $2.00 per year
" IN COUNTRIES OF THE POSTAL UNION, - - 2.25 " "

The editors solicit communications on all subjects having any bearing on Meteorology, or Climatology. Correspondence on events of current interest is invited, and accounts of local newspapers concerning them will be welcome. Notes on local climate will be published and the columns of the JOURNAL are freely open for worthy communications on all matters within its scope. The editors do not hold themselves responsible for any communications which may be signed or attributed to other authorship than their own.

Contributors will be furnished free with five copies of the issue in which their articles appear. Additional copies can be furnished them at the rate of 12 for $2.00. Reprints will be furnished, with cover and title, at the rate of $6.00 per hundred for anything less than one form (16 pages); $12.00 between one and two forms; and $6.00 for each additional form or fraction. The order for reprints must accompany the copy.

Communications relating to the contents of the JOURNAL may be sent to either editor. Subscriptions and all other letters relating to business matters, should be sent to the

AMERICAN METEOROLOGICAL JOURNAL CO.,
Ann Arbor, Mich.

JUST OUT!

RESEARCHES IN ELECTRO-ALLOTROPIC PHYSIOLOGY

Containing much scientific information and many valuable abstracts on Electro-Therapeutics. This handsome 115 pp. pamphlet will be mailed for only 24 cents in stamps to those who mention "THE AMERICAN METEOROLOGICAL JOURNAL." Address,

JEROME KIDDER M'F'G CO., 820 Broadway New York, N. Y.

Chicago, Milwaukee & St. Paul R'y.

Steam Heated and Electric Lighted Vestibuled Trains to St. Paul and Minneapolis.

Finest Dining Cars in the World.

Through Sleeping Cars to Denver.

The Route of the first "Golden Gate Special."

Excursion Tickets to Colorado.

Excursion Tickets to California.

Everything First-Class.

First-Class People patronize First-Class Lines.

Ticket Agents everywhere sell Tickets over the Chicago, Milwaukee & St. Paul Railway.

NORTHERN PACIFIC RAILROAD

LANDS FOR SALE.

The Northern Pacific Railroad Company has a large quantity of very productive and desirable AGRICULTURAL AND GRAZING LANDS for sale at LOW RATES and on EASY TERMS. These lands are located along the line in the States and Territories traversed by the Northern Pacific Railroad as follows:

In Minnesota,	- - - -	Upwards of 1,350,000 Acres
In North Dakota,	- - - -	" 7,000,000 Acres
In Montana,	- - - -	" 19,000,000 Acres
In Northern Idaho,	- - - -	" 1,750,000 Acres
In Washington and Oregon,	- - -	" 12,000,000 Acres

AGGREGATING OVER 40,000,000 ACRES.

These lands are for sale at the LOWEST PRICES ever offered by any railroad company, ranging chiefly

FROM $1.25 TO $6.00 PER ACRE, AND ON 5 AND 10 YEARS' TIME,

For the best Wheat Lands, the best diversified Farming Lands, and the best Grazing Lands now open for settlement.

In addition to the millions of acres of low priced lands for sale by the Northern Pacific R. R. Co., on easy terms, there is an equal amount of Government lands lying in alternate sections with the railroad lands, open for entry, free to settlers, under the Homestead, Pre-emption and Tree Culture laws.

DO THIS!

WRITE FOR PUBLICATIONS RELATING TO MINNESOTA, NORTH DAKOTA, MONTANA, NORTHERN IDAHO, WASHINGTON AND OREGON

An attractive belt of country reaching from Lake Superior to the Pacific Ocean and Puget Sound, and noted for its rich natural resources.

The Northern Pacific Railroad Company mail free to all applicants the following **Illustrated Publications, containing valuable maps,** and describing Minnesota, North Dakota, Montana, Idaho, Washington, and Oregon, viz.:

A **SECTIONAL LAND MAP OF NORTH DAKOTA,** showing the Government lands open to settlers, and those taken up, and the railroad lands for sale, and those sold in the district covered by the map.

A **SECTIONAL LAND MAP OF EASTERN WASHINGTON AND NORTHERN IDAHO,** showing the unoccupied and occupied Government lands, the sold and unsold railroad lands, with descriptive matter relating to this portion of the Northern Pacific country.

A **SECTIONAL LAND MAP OF WESTERN AND CENTRAL WASHINGTON,** showing the unoccupied and occupied Government lands, the sold and unsold railroad lands, in Central and Western Washington, including the Puget Sound section, with descriptive matter concerning the extensive timber regions, mineral districts, and the **agricultural and grazing lands.**

A **MONTANA MAP,** showing the Land Grant of the Northern Pacific R. R. Co., and the Government surveys in the district covered by the map, with descriptions of the country, its grazing ranges, mineral districts, forests, and agricultural sections.

ALSO SECTIONAL LAND MAPS OF DISTRICTS IN MINNESOTA.

When writing for publications, include the names and addresses of acquaintances, and publications will be sent to them also.

SUPERB TRAIN SERVICE.

The Northern Pacific passenger trains are equipped with Pullman palace sleeping cars, colonist sleeping cars, dining cars, and first-class coaches. The colonist sleeping cars are run on the daily fast through express trains, without extra charge for berths.

For full information relative to rates, tickets, sleeping and dining cars, and for copies of illustrated publications including the "Wonderland" and "Alice Folder," describing the summer resorts, Yellowstone National Park, California, Alaska, etc., with maps of the Park and line of road, apply to or address

CHAS. S. FEE, Gen'l Pass. and Ticket Ag't, St. Paul, Minn.

☞ WRITE FOR PUBLICATIONS. ☜

They are illustrated, and contain valuable maps and descriptive matter, and are MAILED FREE OF CHARGE to all applicants. For information relating to lands and the Northern Pacific country, address

P. B. GROAT, GENERAL EMIGRATION AGENT, OR **CHAS. B. LAMBORN,** LAND COMMISSIONER.

ST. PAUL, MINNESOTA.

DRAPER'S SELF-RECORDING THERMOMETER.

DESCRIPTION OF THE INSTRUMENT AND DIRECTIONS FOR ITS USE.

SIZE 14 BY 20 INCHES.

Protected by Letters Patent in the United States, Canada, Great Britain, France, Germany, Austria, Hungary and Belgium.

STANDARDIZED AND WARRANTED.

MANUFACTURED BY THE

DRAPER MANUFACTURING COMPANY,

152 FRONT STREET, NEW YORK CITY.

This thermometer gves a permanent and continuous record in ink of the temperature. The chart indicating hours of the day and days of the week, gives the degrees of temperature from 20° below zero to 110° above. All instruments are accurately adjusted and warranted. The record is easily read and absolutely correct. Sold by the leading instrument dealers and opticians throughout the United States and Canada, and by

The DRAPER

MANUFACTURING CO.,

Owners of the United States and foreign patents, 152 Front Street, New York.

COLORADO COLLEGE,

COLORADO SPRINGS, COLORADO.

THE CLASSICAL, LITERARY AND SCIENTIFIC DEPARTMENTS are now strongly equipped.
Special Winter Courses are given in Assaying and Determinative Mineralogy.
Students unable to continue their work in the East on account of Pulmonary diseases or Malaria, in this climate can pursue their studies uninterruptedly, and often regain their health at the same time.
For further information Address President SLOCUM.

ROSE POLYTECHNIC INSTITUTE, TERRE HAUTE, IND.

A SCHOOL OF ENGINEERING.

Well endowed, well equipped departments of Mechanical and Civil Engineering. Electricity Chemistry, Drawing. Extensive Shops and Laboratories. Expenses low. For catalogue address T. C. Mendenhall, Pres.

STANDARD THERMOMETER.

LEGIBLE.

5 inch Dial.

$2.50.

ACCURATE.

8 inch Dial.

$2.50.

(Metallic.)

Special Thermometers for Meteorologists with or without Telemeter attachments.

AGENTS:

THE FAIRBANKS SCALE HOUSES

In the principal cities of the United States.

COMPTOMETER

SPECIALLY ADAPTED TO ALL

METEOROLOGICAL COMPUTATIONS.

Addition

Subtraction

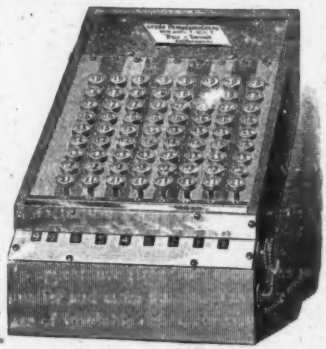
Multiplication

Division

Square Root

Cube Root

Common Fractions.



Operated Entirely by Keys.

Saves 40 per cent of time.

Entire Relief from Mental Strain.

Adapted to all Scientific and Commercial Computations.

ALL Arithmetical Calculations can be solved Rapidly and Accurately by its use. . . . . Send for Circular.

FELT & TARRANT MFG. CO.,

52-56 ILLINOIS STREET, - - CHICAGO, ILL.